THE
POPULAR SCIENCE
MONTHLY.

OCTOBER, 1914

PHENOMENA OF INHERITANCE[1]

By Professor EDWIN G. CONKLIN
PRINCETON UNIVERSITY

A. OBSERVATIONS OF INHERITANCE

THE observations of men in all ages have established the fact that in general "like produces like," and that, in spite of many exceptions, children are in their main characteristics like their parents. And yet offspring are never exactly like their parents, and this has led to the saying that "like does not produce like but only somewhat like." What is meant is that there are general resemblances but particular differences between parents and offspring.

Individuals and Their Characters

In considering organic individuals one may think of them as wholes or as composed of parts, as indivisible unities or as constituent characters; either aspect is a true one and yet neither is complete in itself. Formerly in discussions on heredity the individual was regarded in its entirety and when all hereditary resemblances and differences were averaged it was said that one child resembled the father, another child the mother. This method of lumping together and averaging resemblances and differences led to endless confusion. In heredity, no less than in anatomy, it is necessary to deal with the constituents of organisms; in short, the organism must be analyzed and each part studied by itself. Francis Galton was one of the first to bring order out of chaos by dealing with traits or characters singly instead of treating all together. He made careful studies on the inheritance of weight and size in the seeds of sweet peas, and on the inheritance of stature, eye-color, intellectual capacity, artistic ability and certain diseases in man. At the same time that Galton was thus laying the foundations for a scientific study of heredity by dealing with characters separately,

[1] Third of the Norman W. Harris Lectures for 1914 at Northwestern University on "Heredity and Environment in the Development of Men," to be published by the Princeton University Press.

another and even greater student of heredity, Gregor Mendel, was doing the same thing in his experiments with garden peas, but inasmuch as Mendel's work remained practically unknown for many years, Galton has been rightly recognized as the founder of the scientific study of heredity.

Of course, neither Galton nor any one else, who has followed his method of dealing with the characters of organisms singly, ever supposed that such characters could exist independently of other characters and apart from the entire organism. This is such a self-evident fact that it may seem needless to mention it, and yet there have been critics who have believed, or have assumed to believe that modern students of heredity attempt to analyze organisms into independently existing characters, whereas in most cases they have done only what the anatomist does in treating separately the various organs of the body.

Hereditary Resemblances and Differences

The various characters into which an organism may be analyzed show a greater or smaller degree of resemblance to the corresponding characters of its parents. Whenever the differential cause of a character is a germinal one, the character is, by definition, inherited; on the other hand, whenever this differential cause is environmental the character is not inherited. While it is true that inheritance is most clearly recognized in those characters in which offspring resemble their parents, even characters in which they differ from their parents may be inherited, as is plainly seen when, in any character, a child resembles a grandparent or a more distant ancestor more than either parent. Sometimes actually new characters arise in descendants which were not present in ascendants, but which are thereafter inherited. Accordingly inherited characters may be classified as resemblances and differences, though both are determined by germinal organization, or heredity. There is, therefore, no fundamental difference between inherited similarities and dissimilarities. Heredity and variation are not opposing nor contrasting tendencies which make offspring like their parents in one case and unlike them in another; really inherited characters may be like or unlike those of the parents.

On the other hand, many resemblances and differences between parents and offspring are not due to heredity at all, but to environmental conditions. By means of experiment it is possible to distinguish between hereditary and environmental resemblances and differences, but among men where experiments are generally out of the question it is often difficult or impossible to make this distinction.

I. *Hereditary Resemblances*

1. *Racial Characters.*—All peculiarities which are characteristic of a race, species, genus, order, class and phylum are of course inherited,

otherwise there would be no constant characteristics of these groups and no possibility of classifying organisms. The chief characters of every living thing are unalterably fixed by heredity. Men do not gather grapes of thorns nor figs of thistles. Every living thing produces offspring after its own kind. Men, horses, cattle; birds, reptiles, fishes; insects, mollusks, worms; polyps, sponges, microorganisms—all of the million known species of animals and plants differ from one another because of inherited peculiarities—because they have come from different kinds of germ cells.

2. *Individual Characters.*—Many characters which are peculiar to certain individuals are known to be inherited, and in general use the word inheritance refers to the repetition in successive generations of such individual peculiarities. Among such individual characters are the following:

(*a*) *Morphological Features.*—Hereditary resemblances are especially recognizable in the gross and minute anatomy of every organism in the form, structure, location, size, color, etc., of each and every part. The number of such individual peculiarities which are inherited is innumerable and only a few of the more striking—of the greatest and smallest of these can be mentioned.

It is a matter of common knowledge that unusually great or small stature runs in certain families, and Galton developed a formula for determining the approximate stature of children from the known stature of the parents and from the mean stature of the race. However his statistical and mathematical formulæ give only general or average results, from which there are many individual departures and exceptions.

In the same way the color of the skin, the color and form of hair, and the color of eyes are, in general, like those of one or more of the parents or grandparents. We all know that certain facial features such as the shape and size of eyes, nose, mouth and chin are generally characteristic of certain families.

But the inheritance of anatomical features extends to much more minute characters than those just mentioned. In certain families a few hairs in the eyebrows are longer than the others; or there may be patches of parti-colored hair over the scalp; or dimples in the cheek, chin, or other parts of the skin may occur; and these trifling peculiarities are inherited with all the tenacity shown in the transmission of more important characters. Johannsen has found races of beans in which the average weight of individual seeds differed only by .02 to .03 gram, and yet these minute differences in weight were characteristic of each race and were of course inherited. Jennings has found races of paramecium which show hereditary differences of .005 mm. in length (Fig. 46). Nettleship says that the lens of the human eye weighs only about 175 milligrams, or about one three millionth part

of the body weight, and in hereditary cataract only about one twentieth part of the lens becomes opaque, and yet this minute fraction of the body weight shows the influence of heredity. Even the size, shape and

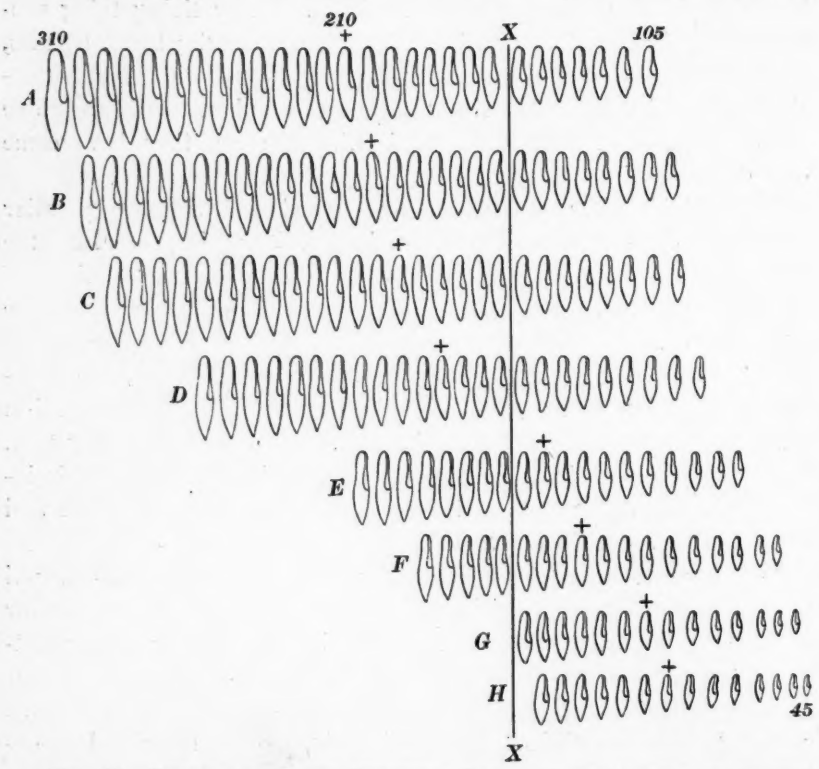


FIG. 46. DIAGRAM OF EIGHT DIFFERENT RACES OF PARAMECIUM, EACH HORIZONTAL ROW (*A*-*H*) REPRESENTING A SINGLE RACE. The individual showing the mean size in each race is indicated by + ; the mean of all the races is shown by the line *X*-*X*. The numbers are the length in microns (one thousandth of a millimeter), × 43. (After Jennings.)

number of the cells in certain organs, and in given embryonic stages, may be repeated generation after generation; and if our analysis were sufficiently complete we should doubtless find that even the minute parts of cells, such as nuclei, chromosomes and centrosomes, show individual peculiarities which are inherited.

(*b*) *Teratological and Pathological Peculiarities* are really only unusual or abnormal anatomical characters, but of such interest and importance as to deserve special mention. Many such abnormalities are undoubtedly inherited, among which are the following: polydactylism, in which more than the normal number of digits are present; syndactylism, or a condition of webbed fingers and toes; brachydactylism, in which the fingers are short and stumpy and usually contain less than the normal number of joints; acondroplasy, or short and crooked limbs, such as occur in certain breeds of dogs and sheep and in certain hu-

man dwarfs; myopia in which the eyeball is elongated; glaucoma or swelling of the eyeball; coloboma, or open suture of the iris; otosclerosis, or thickened tympanic membrane, causing "hardness of hearing"; some forms of deaf-mutism, due to certain defects of the inner ear; and many other characters too numerous to mention here. On the other hand many abnormal or monstrous conditions are due to abnormal environment and are not inherited.

The question of the inheritance of diseases may be briefly considered here. If a disease is due to some defect in the hereditary constitution, it is inherited; otherwise, according to our definition of heredity, it is not. Of course no disease develops without extrinsic causes but when one individual takes a disease while another under the same conditions does not, the differential cause may be an inherited one, or it may be due to differences in the previous conditions of life. There is no doubt that certain diseases run in families and have the appearance of being inherited, but in this case as in many others it is extremely difficult in the absence of experiments to distinguish between effects due to intrinsic causes and those due to extrinsic ones. Where the specific cause of a disease is some microorganism the individual must have been infected at some time or other, almost invariably after birth. In few instances, is the oosperm itself infected, and even when it is this is not, strictly speaking, a case of inheritance, but rather one of early infection. Pearson has found that there is a marked correlation (represented by the number .55 when complete correlation is 1) between the tuberculous parents and tuberculous children, but there is very little evidence that the child is ever infected before birth. What is inherited in this case is probably slight resistance to the tubercle bacillus. There is evidence that almost all adult persons have been infected at one time or another by this bacillus, but it has not developed far in all of them because some have superior powers of resistance. Such greater or smaller resistance, stronger or weaker build, is inherited, and while diminished resistance is not the direct cause of tuberculosis it is a predisposing cause. The same is probably true of many other diseases, the immediate causes of which are extrinsic, while only the more remote, or predisposing causes, are hereditary.

(*c*) *Physiological peculiarities* are inherited as well as morphological ones; indeed function and structure are only two aspects of one and the same thing, namely, organization. For all morphological characters there are functional correlatives, for functional characters morphological expressions, and if the one is inherited so is the other. But there are certain characters in which the physiological aspect is more striking than the morphological one. For example, longevity is a physiological character which is undoubtedly dependent upon many causes, but in the case of species which differ greatly in length of life there can be little

doubt that we are dealing with an inherited character. The great differences in the length of life of an elephant and a mouse, of a parrot and a pigeon, of a cicada and a squash bug, are as surely the result of inherited causes as are the differences in structure between those animals. Within the same species different races or lines show characteristic differences in length of life; in the case of man the average length of life is much greater in some families than in others, and life insurance companies take account of this fact. Even within the same organism certain organs or cells are short-lived, whereas others are long-lived; some cells and organs live only through the early embryonic period, while others live as long as the general organism.

Obesity is another physiological character which may be inherited; the members of certain families grow fat in spite of themselves, while other families remain thin however well fed they may be. Here also many factors enter into the result, but it seems probable that the differentiating factor is a hereditary one. Baldness affects the male members of certain families when they have reached a given age, while in others neither care, dissipation nor age can rob a man of his bushy top. Hemophilia, or excessive bleeding, after an injury, which is due to a deficiency in the clotting power of the blood, is strongly inherited in the male line in certain families. Fecundity and a tendency to bear twins or triplets, left-handedness, a peculiar lack of resistance to certain diseases, and many other physiological peculiarities are probably inherited.

(*d*) *Psychological characters* appear to be inherited in the same way that anatomical and physiological traits are; indeed all that has been said regarding the correlation of morphological and physiological characters applies also to psychological ones. No one doubts that particular instincts, aptitudes and capacities are inherited among both animals and men, nor that different races and species differ hereditarily in psychological characteristics. Certain breeds of dogs such as the mastiff, the bull dog, the terrier, the collie, and many others, are characterized by peculiarities of temperament, affection, intelligence and disposition. No one who has much studied the subject can doubt that different human races and families show characteristic differences in these same respects. It is quite futile to argue that exceptional individuals may be found in one race with the mental characteristics of another race; the same could be said of different races of dogs, or of the sizes of different races of beans or of paramecia. The fact is that racial characteristics are not determined by exceptional and extreme individuals but by the average or mean qualities of the race; and measured in this way there is no doubt that certain types of mind and disposition are characteristic of certain families.

There is no longer any question that some kinds of feeble-minded-

ness, epilepsy and insanity are inherited, and that there is often a hereditary basis for nervous and phlegmatic temperaments, for emotional, judicial and calculating dispositions. Nor can it be denied that strength or weakness of will, a tendency to moral obliquity or rectitude, capacity or incapacity for the highest intellectual pursuits, occur frequently in certain families and appear to be inherited. In spite of certain noteworthy exceptions, which may perhaps be due to remarkable variations, statistics collected by Galton show that genius is hereditary; while the work of certain recent investigators, particularly Goddard, Davenport and Weeks, proves that feeble-mindedness and epilepsy are also inherited; and the careful work of Mott and of Rosanoff leaves no room for doubt that certain types of insanity are hereditary. It frequently happens that families in which hereditary insanity occurs also have other members afflicted with epilepsy, hysteria, alcoholism, etc., which would indicate that the thing inherited is an unstable condition of the nervous system which may take various forms under slightly different conditions. Woods has collected data concerning "Heredity in Royalty" which seem to show that very high or low grades of intellect and virtues may be traced through the royal families of Europe for several generations.

The general trend of all recent work on heredity is unmistakable, whether it concerns man or lower animals. The entire organism, consisting of structures and functions, body and mind, develops out of the germ, and the organization of the germ determines all the *possibilities* of development of the mind no less than of the body, though the actual realization of any possibility is dependent also upon environmental stimuli.

II. *Hereditary Differences*

There are many limitations or exceptions to the general rule that children resemble their parents. Sometimes these differences are due to new combinations of ancestral characters, sometimes they are actually new characters not present so far as known in any of the ancestors, though even such new characters must arise from new combinations of the *elements* of old characters, as we shall see later.

1. *New Combinations of Characters.*—In all cases of sexually produced organisms new combinations of ancestral characters are evident. Usually a child inherits some traits from one parent and other traits from the other parent, so that it is a kind of mosaic of ancestral traits. Such inheritance, bit by bit, of this character from one progenitor and that from another was described by Galton as "particulate" (Fig. 47). On the other hand Galton supposed that in some instances a child might inherit all or nearly all of his traits from one parent; such inheritance he called "alternative" (Fig. 47).

In other cases the traits of the parents appear to blend in the offspring,

as for example, in the skin color of mulattoes; such cases were called by Galton "blending" inheritance (Fig. 47). Sometimes characters appear in offspring which were "latent" in the parents but were "patent" in one or more of the grandparents; such skipping of a generation, during which a character remains "latent," has long been known as "atavism." At other times characters which were present in distant ancestors, but which have since dropped out of sight, or have remained "latent," reappear in descendants; such cases are known as "reversions."

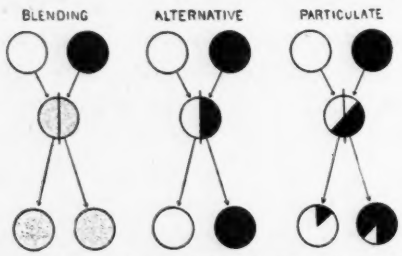


FIG. 47. DIAGRAM OF GALTON'S "LAW OF ANCESTRAL INHERITANCE." The whole heritage is represented by the entire rectangle; that derived from each progenitor by the smaller squares; the number of the latter doubles in each ascending generation while its area is halved. After Thompson.)

In still other cases certain characters appear only in the male sex, others only in the female, this being called "sex-limited" inheritance; while in some instances characters are transmitted from fathers through daughters to grandsons or from mothers to sons, all such cases being known as "sex-linked" inheritance.

2. *New Characters or Mutations.*—But in addition to these permutations in the distribution and combination of ancestral characters new and unexpected characters sometimes develop in the offspring, which were not present, so far as shown, in any of the ascendants, but which, after they have once appeared, are passed on by heredity to descendants. Such inherited variations are usually of two kinds, continuous or slight, and discontinuous or sudden variations. The latter are especially noticeable when variations occur in the normal number of parts, as in four-leaved clover, or six-fingered men, and such numerical variations have been called by Bateson "meristic." However sudden variations may include any marked departure from the normal type, in color, shape, size, chemical compositions, etc. Such sudden variations have long been known to breeders as "sports," and both Darwin and Galton pointed out the fact that such sports have sometimes given rise to new races or breeds, though Darwin was not inclined to assign much importance to them in the general process of evolution. Galton, on the other hand, maintained that variations, or what would now be called "continuous variations," can not be of much significance in the process of evolution, but that the case is quite different with "sports." [2]

More recently the entire biological world has been greatly influenced by the "mutation theory" of deVries, which has placed a new emphasis upon the importance of sudden variations in the process of evolution. At first deVries was inclined to emphasize the degree of difference be-

[2] "Hereditary Genius," Prefatory Chapter.

tween discontinuous and continuous variations, but in later works this distinction is given a minor place as compared with the distinction between inherited and non-inherited variations. Inherited variations, whether large or small, are called by deVries "mutations," whereas non-inherited variations are known as "fluctuations," the former are caused by changes in germinal constitution, the latter by alterations in environmental conditions; the former represents changes in heredity, the latter changes in development.

3. *Mutations and Fluctuations.*—This clear cut distinction between mutations and fluctuations marks one of the most important advances ever made in the study of development and evolution. Thousands of fluctuations occur which are purely somatic in character and which do not affect the germ cells, for every single mutation or change in the hereditary constitution; and yet only the latter are of significance in heredity and evolution. This distinction between variations due to environment (fluctuations) and those due to hereditary causes (mutations) was recognized by Weismann and many of his followers, but the actual demonstration on a large scale of the importance of this distinction is due largely to deVries.

All hereditary variations, whether due to new combinations of old characters or to the appearance of actually new characters, whether small and continuous, or large and discontinuous, have their causes in the organization of the germ cells, just as do inherited resemblances. Heredity is not to be contrasted with variation, nor are hereditary likeness and unlikeness due to conflicting principles; both are the results of germinal organization and both are phenomena of heredity.

4. *Every Individual Unique.*—As a result of the permutations of ancestral characters, the appearance of mutations, and the fluctuations of organisms due to environmental changes, it happens that in all cases offspring differ more or less from their parents and from one another. No two children of the same family are ever exactly alike (except in the case of identical twins which have come from the same oosperm). Every living being appears on careful examination to be the first and last of its identical kind. This is one of the most remarkable peculiarities of living things. The elements of chemistry are constant, and even the compounds fall into definite categories which have constant characteristics. But the individuals of biology are apparently never twice the same. This may be due to the immense complexity of living units as contrasted with chemical ones, indeed lack of constancy is evident in itself of lack of analysis into real elements or of lack of uniform conditions, but whatever its cause the extraordinary fact remains that every living being appears to be unique.

There seems to be no reason to doubt that all the extraordinary dif-

Reproduction is the generation of unique beings that are, on the average, more like their kind than like anything else (Brooks).

ferences which organisms show, as well as all of their resemblances, are due to differences or resemblances in the hereditary and environmental factors which have been operative in their development. But in view of this universal variability of organisms it is not surprising that inheritance has seemed capricious and uncertain—"a sort of maze in which science loses itself."

B. STATISTICAL STUDY OF INHERITANCE

Francis Galton was one of the first who attempted to reduce the mass of conflicting observations on heredity and variation to some system and to establish certain principles as a result of statistical study. He was the real founder of the scientific study of inheritance, he created characters singly and he introduced quantitative measures. Galton's researches, which were published in several volumes, consisted chiefly in a study of certain families with regard to several selected traits, viz., genius or marked intellectual capacity, artistic faculty, stature, eye color and disease. As a result of his very extensive studies two main principles appeared to be established:

1. *The Law of Ancestral Inheritance* which he stated as follows:

The two parents contribute between them on the average one half of each inherited faculty, each of them contributing one quarter of it. The four grandparents contribute between them one quarter, or each of them one sixteenth; and so on, the sum of the series $1/2 + 1/4 + 1/8 + 1/16 \ldots$ being equal to 1, as it should be. It is a property of this infinite series that each term is equal to the sum of all those that follow: thus $1/2 = 1/8 + 1/16 + \ldots$, $1/4 = 1/8 + 1/16 + \ldots$, and so on. The prepotencies of particular ancestors in any given pedigree are eliminated by a law which deals only with average contributions, and the various prepotencies of sex with respect to different qualities are also presumably eliminated.

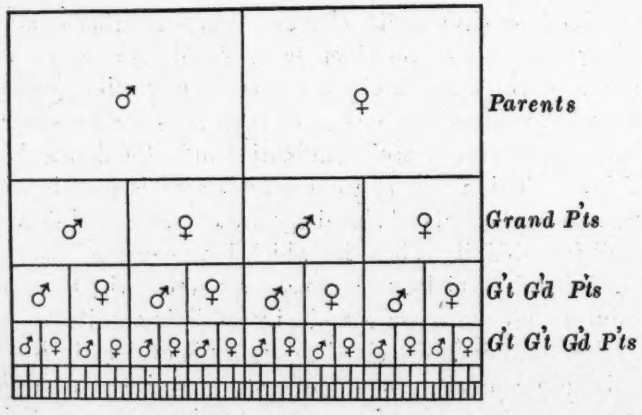


FIG. 48. SCHEME TO ILLUSTRATE GALTON'S "LAW OF FILIAL REGRESSION" AS SHOWN IN THE STATURE OF PARENTS AND CHILDREN. The mean height of all parents is shown by the dotted line between 68 and 69 inches. The circles through which the diagonal line runs represent the heights of graded groups of parents and the arrow heads indicate the average heights of their children. The offspring of undersized parents are taller and of oversized parents are shorter than their respective parents. (From Walter.)

The average contribution of each ancestor was thus stated definitely, the contribution diminishing with the remoteness of the ancestor. This Law of Ancestral Inheritance is represented graphically in the accompanying diagram (Fig. 48). Pearson has somewhat modified the figures given by Galton, holding that in horses and dogs the parents contribute ½, the grandparents ⅓, the great grandparents 2/9, etc.

Theoretically the number of ancestors doubles in each ascending generation; there are two parents, four grandparents, eight great-grandparents, etc. If this continued to be true indefinitely the number of ancestors in any ascending generation would be $(2)^n$, in which n represents the number of generations. There have been about 57 generations since the beginning of the Christian Era, and if this rule held true indefinitely each of us would have had at the time of the birth of Christ a number of ancestors represented by $(2)^{57}$ or about 120 quadrillions—a number far greater than the entire human population of the globe at that time. As a matter of fact, owing to the intermarriage of cousins of various degrees the actual number of ancestors is much smaller than the theoretical number. For example, Plate says that the present Emperor of Germany had only 162 ancestors in the 10th ascending generation, instead of 512, the theoretical number. Nevertheless this calculation will serve to show how widespread our ancestral lines are, and how nearly related are all people of the same race.

Davenport concludes that no people of English descent are more distantly related than 30th cousins, while most people are much more closely related than that. If we allow three generations to a century, and calculate that the degree of cousinship is determined by the number of generations less two, since first cousins appear only in the third generation, the first being that of the parents and the second that of the sons and daughters, we find that 30th cousins at the present time would have had a common ancestor about one thousand years ago or approximately at the time of William the Conqueror. As a matter of fact most persons of the same race are much more closely related than this, and certainly we need not go back to Adam nor even to Shem, Ham and Japhet, to find our common ancestor.

2. The second principle which Galton deduced from his statistical studies is known as the *Law of Filial Regression,* or what might be called the tendency to mediocrity. He found that on the average extreme peculiarities of parents were less extreme in children. "The stature of adult offspring must, on the whole, be more mediocre than the stature of their parents, that is to say more near to the mean or mid of the general population"; and again, "the more bountifully a parent is gifted by nature, the more rare will be his good fortune if he begets a son who is as richly endowed as himself." This so-called law of filial regression is represented graphically in Fig. 49 in which the actual

stature of individual parents is shown by the oblique line, the stature of children by the dotted curve, and the mean stature of the race in the horizontal dotted line.

One of the chief aims and results of statistical study is to eliminate individual peculiarities and to obtain general and average results.

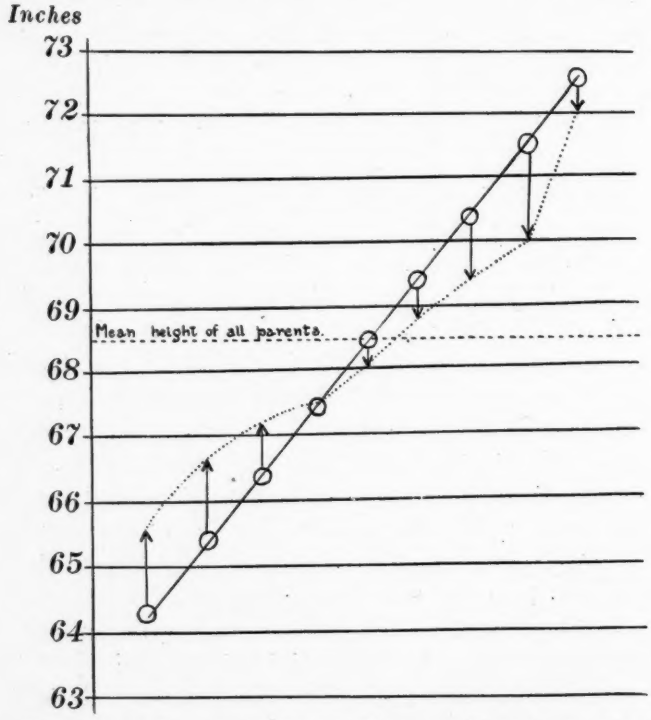


FIG. 49. DIAGRAM TO ILLUSTRATE THREE KINDS OF INHERITANCE DESCRIBED BY GALTON. (After Walter.)

Such work may be of great importance in the study of heredity, especially where questions of the occurrence or distribution of particular phenomena are concerned; but the causes of heredity are individual and physiological, and averages are of less value in finding the causes of such phenomena than is the intensive study of individual cases.

By observation alone it is usually impossible to distinguish between inherited and environmental resemblances and differences, and yet this distinction is essential to any study of inheritance. If all sorts of likenesses and unlikenesses are lumped together, whether inherited or not, our study of inheritance can only end in confusion. The value of statistics depends upon a proper classification of the things measured and enumerated, and if things which are not commensurable are grouped together the results may be quite misleading and worthless. Unfortunately Galton and Pearson, as well as some of their followers, have not carefully distinguished between hereditary and environmental characters.

Furthermore much of their material was drawn from a general population in which were many different families and lines not closely related genetically. Consequently their statistical studies are of little value in discovering the physiological principles or laws of heredity. Jennings (1910) well says,

> **Galton's laws of regression and of ancestral inheritance are the product mainly of a lack of distinction between two absolutely diverse things, between non-inheritable fluctuations, on the one hand, and permanent genotypic differentiations, on the other.**

In the case of man we have few certain tests to determine whether the differential cause of any character is hereditary or environmental, but in the case of animals and plants, where experiments may be performed on a large scale it is possible to make such tests by (1) experiments in which environment is kept as uniform as possible while the hereditary factors differ, and (2) experiments in which, in a series of cases, the hereditary factors are fairly constant while the environment differs. In this way the differential cause or causes of any character may be located in heredity, in environment, or in both.

The observational and statistical study of inheritance helped to outline the problem but did little to solve it. Certain phenomena of hereditary resemblances between ascendants and descendants were made intelligible, but there were many peculiar and apparently irregular or lawless phenomena which could not be predicted before they occurred nor explained afterwards. For example when Darwin crossed different breeds of domestic pigeons, no one of which had a trace of blue in its plumage, he sometimes obtained offspring with more or less of the blue color and markings of the wild rock pigeon from which domestic pigeons are presumably descended. He described many cases of dogs, cattle and swine, as well as many cultivated plants, in which offspring resembled distant ancestors and differed from nearer ones; such cases had long been known and were spoken of as "reversion." He observed many cases in which certain characters of one parent prevailed over corresponding characters of the other parent in the offspring, this being known as "prepotency"; but there was no satisfactory explanation of these curious phenomena. They did not come under either of Galton's laws, and their occurrence was apparently so irregular that every such case seemed to be a law unto itself.

C. EXPERIMENTAL STUDY OF INHERITANCE

I. *Mendelism*

The year 1900 marks the beginning of a new era in the study of inheritance. In the spring of that year three botanists, deVries, Correns and Tschermak, discovered independently an important principle of

heredity and at the same time brought to light a long neglected and forgotten work on "Experiments in Plant Hybridization" by Gregor Mendel, in which this same principle was set forth in detail. This principle is now generally known as "Mendel's Law." Mendel, who was a monk and later abbot of the *Königskloster,* an Augustinian monastery in Brünn, Austria, published the results of his experiments on hybridization in the *Proceedings of the Natural History Society of Brünn* in 1866. The paper attracted but little attention at the time although it contained some of the most important discoveries regarding inheritance which had ever been made, and it remained buried and practically unknown for thirty-five years. Plant hybridization had been studied extensively before Mendel began his work, but he carried on his observations of the hybrids and of their progeny for a longer time and with greater analytical ability than any previous investigator had done. The methods and results of his work are so well known through the writings of Bateson, Punnett and many others, that it is unnecessary to dwell at length upon them here. In brief Mendel's method consisted in crossing two forms having distinct characters, and then in counting the number of offspring in successive generations showing one or the other of these characters.

During the eight years preceding the publication of his paper in 1866 Mendel hybridized some twenty-two varieties of garden peas. This group of plants was chosen because the different varieties could be cross-fertilized or self-fertilized and were easily protected from the influence of foreign pollen; because the hybrids and their offspring remained fertile through successive generations; and because the different varieties are distinguished by constant differentiating characters. Mendel devoted his attention to seven of these characters, which he followed through several generations of hybrids, viz.,

(1) Differences in the form of the ripe seeds, whether round or wrinkled.

(2) Differences in the color of the food material within the seeds, whether pale yellow, orange or green.

(3) Differences in the color of the seed coats (and in some cases of the flowers also), whether white, gray, gray brown, leather brown, with or without violet spots.

(4) Differences in the form of the ripe pods, whether simply inflated or constricted between the seeds.

(5) Differences in the color of the unripe pods whether light to dark green, or vividly yellow.

(6) Differences in the positions of the flowers, whether axial, that is distributed along the stem, or terminal, that is bunched at the top of the stem.

(7) Differences in the length of the stem, whether tall or short.

1. *Results of Crossing Individuals with one Contrasting Character.* —Having determined that these characters were constant for certain varieties or species Mendel then proceeded to cross one variety with another, by carefully removing the unripe stamens, with their pollen, from the flowers of one variety and dusting upon the stigma of such flowers the pollen of a different variety. In this way he crossed vari-

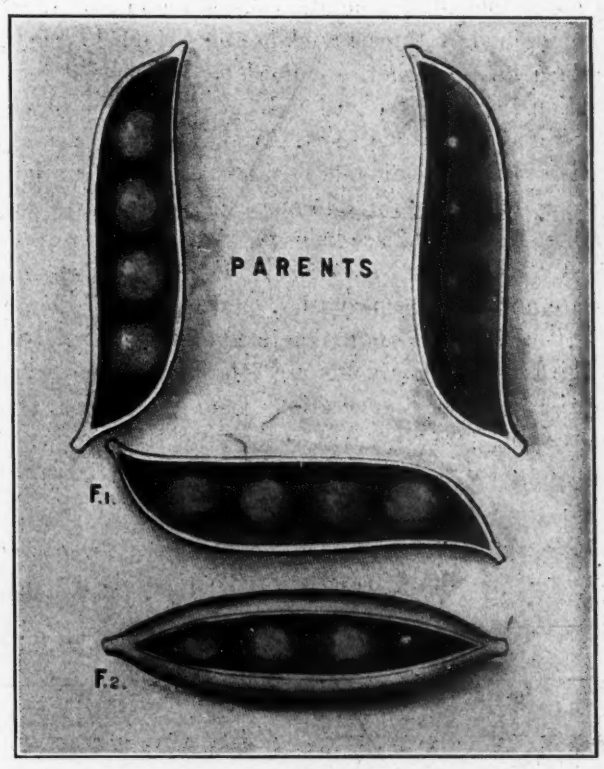


FIG. 50. DIAGRAM SHOWING THE RESULTS OF CROSSING YELLOW-SEEDED (LIGHTER COLORED) AND GREEN-SEEDED (DARKER COLORED) PEAS. From Morgan after Thompson.)

eties of peas which differed from each other in some one of the characters mentioned above, and then studied the offspring of several successive generations with respect to this character.

In every case he discovered that the plants that developed from such a cross showed only one of the two contrasting characters of the parent plants, *i. e.*, all were round-seeded, yellow seeded, tall, etc., although one of the parents had wrinkled seeds, green seeds, or short stem, etc.

Those characters which are transmitted entire or almost unchanged in the hybridization are termed *dominant* and those which become latent in the process, *recessive.*

These hybrids[3] when self-fertilized gave rise to a second filial generation of individuals some of which showed the dominant character and others the recessive, the relative numbers of the two being approximately three to one. Thus the hybrids produced by crossing yellow-seeded and green-seeded peas yielded when self-fertilized 6,022 yellow seeds and 2,001 green seeds, or almost exactly three yellow to one green (Fig. 50). The hybrids produced by crossing round and wrinkled seeded varieties yielded in the second filial generation 5,474 round and 1,850 wrinkled seeds, or approximately three round to one wrinkled (Fig. 53). The hybrids from a tall and short stemmed cross produced in the second filial generation 787 long stemmed and 277 short stemmed, or again approximately three tall to one short. And in every other case Mendel found that the ratio of dominants to recessives in the second filial generation was approximately three to one. These recessives derived from hybrid parents are pure and are known as "extracted" recessives; when self-fertilized they produce recessives indefinitely. One third of the dominants are also pure homozygotes, or "extracted" dominants, and when self-fertilized produce pure dominants indefinitely. On the other hand, two thirds of the dominants are heterozygotes and when self-fertilized give rise in the next generation to pure dominants, mixed dominant-recessives and pure recessives in the proportion of 1:2:1. These general results are summarized in the accompanying diagram (Fig. 51)

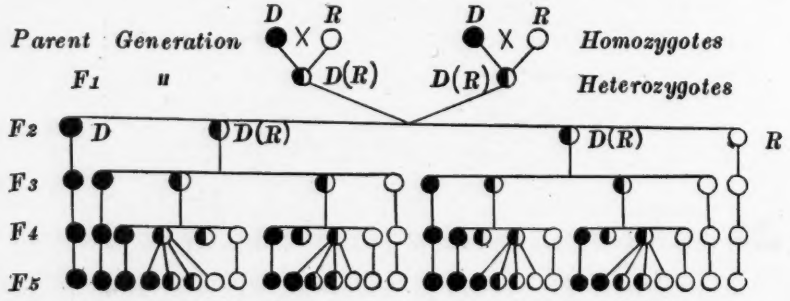


FIG. 51. DIAGRAM SHOWING RESULTS OF MENDELIAN SPLITTING WHERE THE PARENTS ARE PURE DOMINANTS AND PURE RECESSIVES (HOMOZYGOTES). All pure dominants are represented by black circles, all pure recessives by white ones, while mixed dominant-recessives (heterozygotes) are represented by circles half white and half black. Successive generations are marked F_1 F_2, F_3, etc.

in which dominant characters are indicated by the letter *D*, recessive characters by *R*, and mixed dominant-recessives, with the recessive character unexpressed, by *D* (*R*); while *DD* or *RR* indicate extracted dominants or recessives, that is, pure dominants or recessives which have

[3] Bateson introduced the term *homozygote* for *pure bred* individuals resulting from the union of gametes which are hereditarily similar, and *heterozygote* for *hybrids* resulting from the union of hereditarily dissimilar gametes. The gametes formed from a homozygote are all of the same hereditary type, those formed from a heterozygote are of two or more different types.

separated out from mixed dominant-recessives, D (R). The parental generation is indicated by the letter P, and the successive filial generations by F_1, F_2, F_3, etc.

In the case of the peas studied by Mendel the hybrids of the F_1 generation show only the dominant character, the contrasted recessive character being present but not expressed. However in certain cases it has been found that the hybrids differ from either parent and in successive generations split up into both parental types and into the hybrid type; thus Correns found that when a white flowered variety of Mirabilis, the four o'clock, was crossed with a red flowered variety all of the hybrids in the F_1 generation had pink flowers and from those in the F_2 generation there came white-flowered, pink-flowered and red-flowered forms in the proportion of 1 white : 2 pink : 1 red, as shown in Fig. 56. This is a better illustration of Mendel's principle of splitting than is offered by the peas, since in this case the mixed dominant-recessives $D(R)$ are always distinguishable from the pure dominants DD.

In the F_2 generation and in all subsequent ones the pure dominants, and the pure recessives always breed true when self-fertilized, whereas the mixed dominant-recessives continue to split up in each successive generation into pure dominants, mixed dominant-recessives and pure recessives in the proportion 1 : 2 : 1. The result of this is that the relative number of dominants and recessives increases in successive generations, whereas the relative number of mixed dominant-recessives decreases, and in a few generations a hybrid race will revert in large part to its parental types if continued hybridization is prevented. On the other hand there is no tendency for the relative number of dominants to increase and of recessives to decrease in successive generations; an equal number of pure dominants and pure recessives is produced in each generation.

With remarkable insight Mendel recognized that the real explanation of the splitting of pure recessives and pure dominants from hybrid parents must be found in the composition of the male and female sex cells. Since such extracted dominants and recessives breed true, just as pure species do, it must be that their germ cells are pure. In the cross between pure races of white and red-flowered *Mirabilis* the germ cells which unite in fertilization must be pure with respect to white and red, though the individual which develops from this cross is a pink hybrid. But the fact that one quarter of the progeny of this hybrid are pure white, and another quarter pure red, and that these thereafter breed true, proves that the hybrid produces germ cells which are pure with respect to red and white. Furthermore the fact that one half the progeny of this hybrid are themselves hybrid may be explained by assuming that they were produced by the union of germ cells carrying pure white and pure red, as in the first cross in the parental generation.

Mendel therefore concluded that individual germ cells are always pure with respect to any pair of contrasting characters, even though those germ cells have come from hybrids in which the contrasting characters are mixed. A single germ cell can carry the factors, or causes, for red *or* white flowers, for green seeds *or* yellow seeds, for tall stem *or* short stem, etc., but not for both pairs of these contrasting characters. The hybrids formed by crossing white and red four o'clocks carry the factors for both white and red, but the individual germ cells formed by such a hybrid carry the factors for white *or* red, but not for both; these factors segregate or separate in the formation of the germ cells so that one half of all the germ cells formed carry the factor for white and the other half that for red.

This is the most important part of Mendel's Law—the central doctrine from which all other of his conclusions radiate. It explains not only the segregation of dominant and recessive characters from a hybrid in which both are present, but also the relative numbers of pure dominants, pure recessives, and mixed dominant-recessives in each generation. For if all germ cells are pure with respect to any particular character the hybrid offspring of any two parents with contrasting characters will produce in equal numbers two classes of germ cells, one bearing the

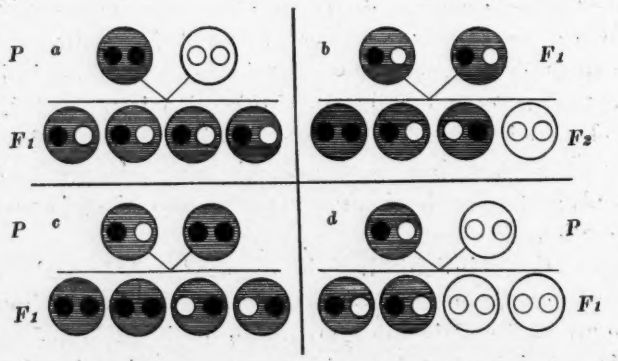
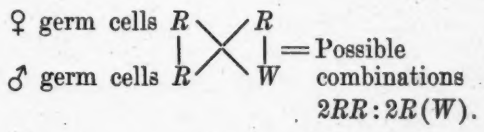


FIG. 52. DIAGRAM OF MENDELIAN INHERITANCE, IN WHICH THE INDIVIDUAL IS REPRESENTED BY THE LARGE CIRCLE, THE GERM CELLS BY THE SMALL ONES, DOMINANTS BEING SHADED AND RECESSIVES WHITE. *a*, Pure dominant × pure recessive = all dominant-recessives, *b*, Dominant-recessive × dominant-recessive = 1 pure dominant: 2 dominant-recessives: 1 pure recessive, *c*, Dominant-recessive × pure dominant = 2 pure dominant: 2 dominant-recessive, *d*, Dominant-recessive × pure recessive = 2 dominant-recessive: 2 pure recessive.

dominant and the other the recessive factor, and the chance combination of these two classes of male and female gametes will yield on the average one union of dominant with dominant, two unions of dominant with recessive and one union of recessive with recessive, thus producing the typical Mendelian ratio, $1DD:2D(R):1RR$, as shown in the accompanying diagram (Fig. 52, *A*, *B*).

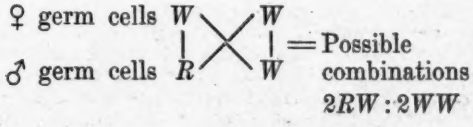
Other Mendelian Ratios

When a pure dominant is crossed with a mixed dominant-recessive all the offspring show the dominant character, though one half are pure dominant and the other half dominant-recessives. Thus if a pure round-seeded variety of pea is crossed with a hybrid between a round and a wrinkled seeded one, all the progeny are round-seeded, though one half of them carry the factor for wrinkled seed; this may be graphically represented as follows:



In subsequent generations the progeny of the pure round (*RR*) breed true and produce only round-seeded peas, whereas the progeny of the hybrid round and wrinkled (*RW*) split up into pure round, hybrid round and wrinkled, and pure wrinkled in the regular Mendelian ratio of $1RR : 2R(W) : 1WW$ (Fig. 52, *C*).

When a pure recessive is crossed with a mixed dominant-recessive another typical ratio results. Thus if a wrinkled-seeded variety of pea is crossed with a hybrid between a round and wrinkled seeded one, round-seeded and wrinkled-seeded peas are produced in the proportion of 1:1. This is due to the fact that the hybrid produces two kinds of germ cells, the pure-bred but one, and the possible combinations of these are as follows:



This ratio of 1:1 is approximately the ratio of the two sexes in many animals and plants, and there is good reason to believe that sex is a Mendelian character of this sort, in which one plant is heterozygous for sex and the other homozygous.

2. *Results of Crossings where there is more than one Contrasting Character.*—It rarely happens that two individuals differ in a single character only; more frequently they differ in many characters and this leads to a great increase in the number of types of offspring in the F_2 generation. But however many pairs of contrasting characters the parents may show each pair may be considered by itself as if it were the only contrasting pair, and when this is done all the offspring may be classified according to the regular Mendelian formula given above.

But when two or more contrasting characters of the parents are followed to the F_2 generation many permutations of these characters occur thus giving rise to a larger number of types of individuals than when a single pair of characters is concerned. When there is only one pair of contrasting characters there are usually but two types of offspring apparent in the F_2 generation, viz., dominants and recessives in the ratio of 3:1 (Fig. 53); where there are two pairs of contrasting

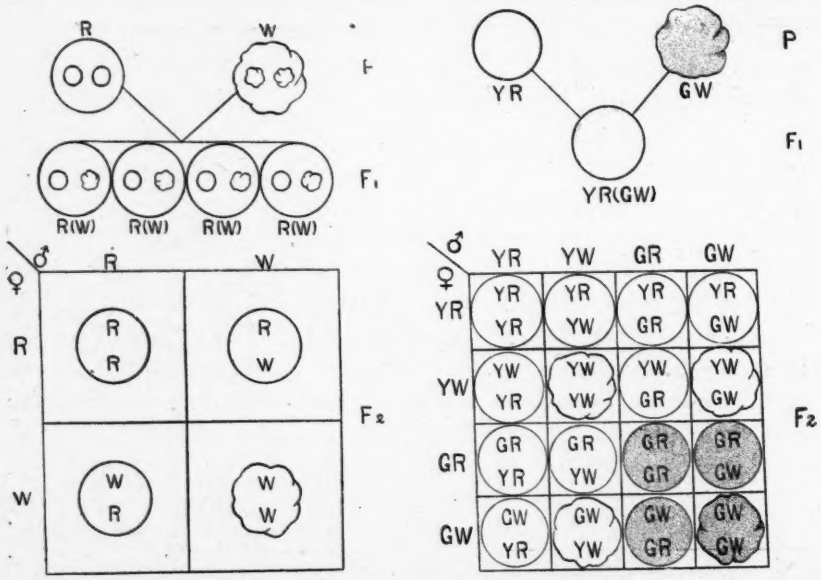


FIG. 53. MONOHYBRID DIAGRAM SHOWING RESULTS OF CROSSING ROUND (*R*) SEEDED WITH WRINKLED (*W*) SEEDED PEAS. Large circles represent zygotes, small ones, or single letters, gametes. In F_1 all individuals are round but contain round and wrinkled gametes. In F_2 the ♂ gametes are placed above the square, the ♀ ones to the left, and the possible combinations of ♂ and ♀ gametes are shown in the small squares, the relative numbers of different types being 1 *RR*:2 *R*(*W*):1 *WW*.

FIG. 54. DIHYBRID DIAGRAM SHOWING RESULTS OF CROSSING PEAS HAVING YELLOW-ROUND (YR) SEEDS WITH OTHERS HAVING GREEN-WRINKLED (GR) ONES. Four types of germ cells are formed by such a hybrid, viz., YR, YW, GR, GW, and the 16 possible combinations (genotypes) of these ♂ and ♀ gametes are shown in the small squares. Since recessive characters do not appear when mated with dominant ones these 16 genotypes produce 4 phenotypes in the following relative numbers: 9YR:3YW:3GR:1GW. There is 1 pure dominant (upper left corner), 1 pure recessive (lower right corner), 4 homozygotes in diagonal line between these corners and 12 heterozygotes.

characters in the parents there are four types of offspring in the F_2 generation in the ratio of $(3:1)^2=9:3:3:1$; when there are three pairs of contrasting characters in the parents there are eight types of offspring apparent in the F_2 generation in the proportions of $(3:1)^3=27:9:9:9:3:3:3:1$, etc. Thus when Mendel crossed a variety of peas bearing round and yellow seeds with another variety having wrinkled and green seeds all the offspring of the F_1 generation bore round and yellow seeds, round being dominant to wrinkled, and yellow to green.

But the plants raised from these seeds, when self-fertilized, yielded seeds of four types, round and yellow (*RY*), wrinkled and yellow (*WY*), round and green (*RG*), and wrinkled and green (*WG*) in the proportion of 9 : 3 : 3 : 1 as shown in figure 54.

In this case also this ratio may be explained by assuming that the germ cells (ovules and pollen) are pure with respect to each of the contrasting characters, round-wrinkled, yellow-green, and therefore any combination of these may occur in a germ cell except the combinations *RW* and *YG*. Accordingly there are four possible kinds of germ cells as follows: $\begin{matrix} Y & & G \\ | & \times & | \\ R & & W \end{matrix}$ *i. e., YR, YW, GR, GW.* Each one of these four kinds of pollen may fertilize each one of the same four kinds of ovules giving rise to sixteen combinations, no two of which are alike, as shown in Fig. 54. The dominant characters are in this case round and yellow, and only when one of these is absent can its contrasting character, wrinkled or green, develop. Accordingly the sixteen possible combinations yield seeds of four different appearances and in the following proportions: 9*RY* : 3*RG* : 3*WY* : 1*WG*. Only one individual in each of these four classes is pure (homozygous) and continues to breed true in successive generations; in Fig. 54 these are found in the diagonal from the upper left to the lower right corner. All other individuals are heterozygous and show Mendelian splitting in the next generation.

When parents differ in three contrasting characters a much larger number of combinations are possible in the F_2 generation. Thus if a pea with round (*R*) and yellow (*Y*) seeds, and with tall (*T*) stem is crossed with one having wrinkled (*W*) and green (*G*) seeds, and dwarf (*D*) stem all the progeny of the F_1 generation have round and yellow seeds and tall stem, *R, Y* and *T* being dominant to *W, G* and *D*. But in the F_2 generation there are sixty-four possible combinations (genotypes) of these six characters; but since a recessive character does not develop if its contrasting dominant character is present there are only eight types which come to expression (phenotypes) and in the following numbers: 27*RYT* : 9*RYD* : 9*RGT* : 3*RGD* : 9*WYT* : 3*WYD* : 3*WGT* : 1*WGD*. Of these sixty-four genotypes only eight are homozygous and breed true (those lying in the diagonal between upper left and lower right corners in Fig. 55), while only one is pure dominant and one pure recessive (in the upper left and lower right corners of Fig. 55).

When the parents differ in one character only, the offspring formed by their crossing are called monohybrids, when there are two contrasting characters in the parents the offspring are dihybrids, when three, trihybrids, and when the parents differ in more than three characters the offspring are called polyhybrids. There are certainly few cases in which parents actually differ in only a single character, but since each contrasting character may be dealt with separately, as if it were the only

one, and since the number of types of offspring increases greatly when more than one or two characters are considered at the same time, it is customary to deal simultaneously with only one or two characters of hybrids, even though the parents may have differed in many characters.

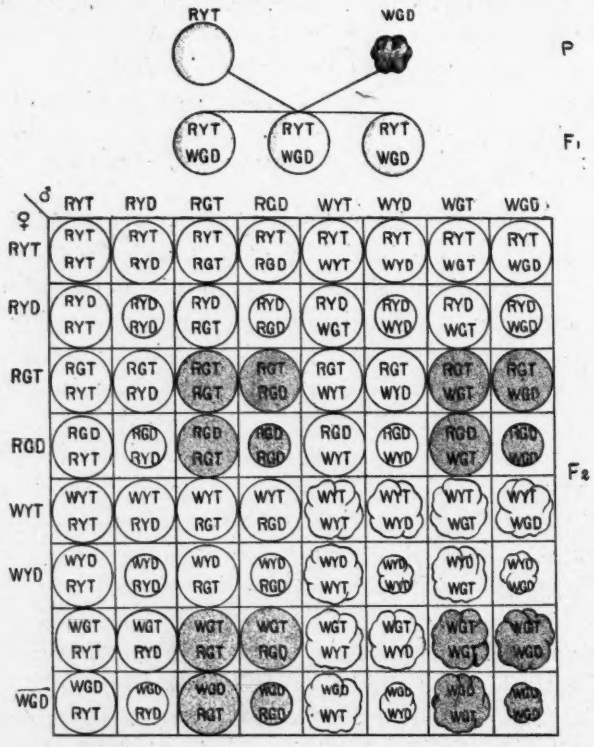


FIG. 55. TRIHYBRID DIAGRAM SHOWING RESULTS OF CROSSING PEAS HAVING ROUND-YELLOW SEEDS AND TALL STEM (RYT) WITH PEAS HAVING WRINKLED GREEN-SEEDS AND DWARF STEM (WGD). Eight types of germ cells result from such a hybrid, as shown in the ♂ gametes above the square and the ♀ ones to the left of it, and the possible combinations (genotypes) of these ♂ and ♀ gametes are shown in the 64 small squares of which only 1 is pure dominant (upper left corner), 1 pure recessive (lower right corner) and 8 homozygotes (in diagonal line between these corners). The relative numbers of the different phenotypes are 27 RYT: 9 RYD:9 RGT:9 WYT:3 RGD:3 WYD:3 WGT:1 WGD.

3. *Inheritance Formulæ.*—Mendel represented the hereditary constitution of the plants used in his experiments by letters employed as symbols, dominant characters being represented by capitals and recessives by small letters. The seven contrasting characters of his peas could be represented as follows:

Seeds, round (*A*), or wrinkled (*a*); yellow (*B*); or green (*b*); with gray seed coats (*C*), or white seed coats (*c*).

Pods, green (*D*), or yellow (*d*); inflated (*E*), or constricted (*e*).

Habit, tall (*F*), or dwarf (*f*).

Flowers, axial (*G*), or terminal (*g*).

It is possible for one plant to have all of these dominant characters or all of the recessive ones, or part of one kind and part of the other. The inheritance formula of a plant having all seven of the dominant characters is *ABCDEFG;* of one having all of the recessive characters *abcdefg*. When two such plants are crossed the inheritance formula of the hybrid is *AaBbCcDdEeFfGg,* and since the dominant and recessive characters (or rather determiners of characters) represented by these seven pairs of letters separate in the formation of the gametes, and since each separate determiner may be associated with either member of the other six pairs, the number of possible combinations of these determiners in the gametes is $(2)^7$ or 128. That is, in this case 128 kinds of germ cells may be produced, each having a different inheritance formula; and since each of these 128 kinds of male germ cells may unite with any one of the 128 kinds of female germ cells, the number of possible combinations is $(128)^2$ or 16,384, which represents the number of combinations of these characters which are possible in the F_2 generation. Every one of these more than sixteen thousand genotypes may be represented by various combinations of the letters *ABCDEFG* and *abcdefg*.

When many characters are concerned it is difficult to remember what each letter stands for, and consequently it is customary in such cases to designate characters by the initial letter in the name of that character. By this form of short hand one can show in a graphic way the possible segregations and combinations of hereditary units in gametes and zygotes through successive generations, and as a result many modern works on Mendelian inheritance look like pages of algebraic formulæ.

Some progress has been made, as was pointed out in the last lecture, in identifying certain structures of the germ cells with certain hereditary units, but quite irrespective of what these units may be and where they may be located it is possible, by means of the Mendelian theory of segregation of units in the germ cells and of chance combinations of these in fertilization to predict the number of genotypes and phenotypes which may be expected as the result of a given cross.

4. *Presence and Absence Hypothesis.*—Mendel spoke of the presence of *contrasting* or *differentiating characters* in the plants which he crossed, such as round or wrinkled seeds, tall or short stems, etc. Many other writers regard these contrasting characters as positive and negative expression of a single character, and consequently they speak of the *presence or absence* of single characters; thus round seeds are due to the presence of a factor for roundness (*A*) while wrinkled seeds are characterized by the absence of that factor (*a*). Round seeds are wrinkled seeds plus the factor for roundness. Most of the phenomena of Mendelian inheritance are more simply stated in terms of presence or absence of single characters than in terms of contrasting characters.

When both gametes carry similar positive factors the zygote has a "double dose" of such factors and is said to be *duplex;* when only one of the gametes carries such a factor the zygote has a "single dose" and is *simplex,* when neither gamete carries a positive factor or factors, the zygote receives only negative factors and is said to be *nulliplex.* Thus the union of gametes *AB* (♀) and *AB* (♂) yields zygote *AABB,* which is duplex in constitution; gametes *Ab* (♀) and *aB* (♂) yield zygote *AaBb,* which is simplex; gametes *ab* (♀) and *ab* (♂) yield zygote *aabb,* which is nulliplex.

In some instances a character comes to full expression only when it is derived from both parents, that is, when it is duplex; if derived from one parent only, that is, if simplex, it is diluted in appearance and is intermediate between the two parents. For example, when white-

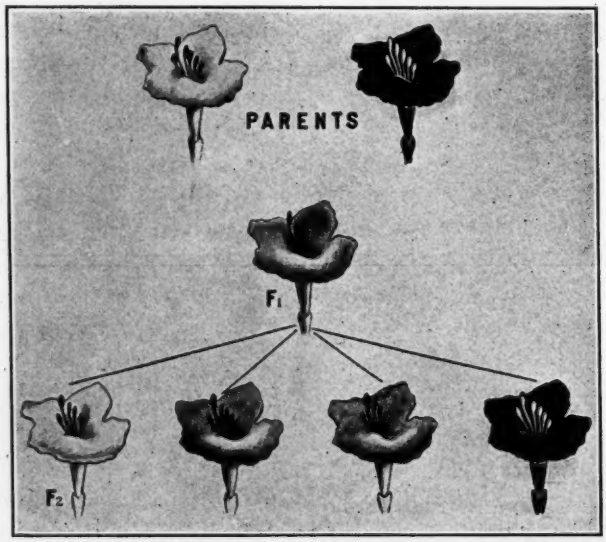


FIG. 56. RESULTS OF CROSSING WHITE-FLOWERED AND RED-FLOWERED RACES OF *Mirabilis Jalapa* (FOUR O'CLOCKS), giving a pink hybrid in F_1, which when inbred gives in F_2 1 white, 2 pink, 1 red. (From Morgan, after Correns.)

flowered four o'clocks which are nulliplex are crossed with red-flowered ones which are duplex the progeny, which are simplex, bear pink flowers; in this case red flowers are produced only when the factor for red is derived from both parents, pink flowers when it is derived from one parent, white flowers when it is derived from neither parent (Fig. 56).

5. *Summary of Mendelian Principles.*—Since the rediscovery in 1900 of Mendel's work many investigators have carried out similar experiments on many species of animals and plants and have greatly extended our knowledge of the principles of inheritance discovered by Mendel, but in the main Mendel's conclusions have been confirmed

again and again, so that there is no doubt that they constitute an important rule of inheritance among all organisms.

In brief the "Mendelian Law of Alternative Inheritance" or of hereditary "splitting" consists of the following principles:

(*a*) *The principle of unit characters.*—The total heritage of an organism may be analyzed into a number of characters which are inherited as a whole and are not further divisible; these are the so-called "unit characters" (deVries).

(*b*) *The principle of dominance.*—When contrasting unit characters are present in the parents they do not as a rule blend in the offspring, but one is dominant and usually appears fully developed, while the other is recessive and temporarily drops out of sight.

(*c*) *The principle of segregation.*—Every individual germ cell is "pure" with respect to any given unit character, even though it come from an "impure" or hybrid parent. In the germ cells of hybrids there is a separation of the determiners of contrasting characters so that different kinds of germ cells are produced, each of which is pure with regard to any given unit character. This is the principle of segregation of unit characters, or of the "purity" of the germ cells. Every sexually produced individual is a double being—double in every cell—one half having been derived from the male and the other half from the female sex cell. This double being, or zygote, again becomes single in the formation of the germ cells only once more to become double when the germ cells unite in fertilization.

(*To be concluded*)

THE CONIFEROUS FORESTS OF EASTERN NORTH AMERICA

By Dr. ROLAND M. HARPER

COLLEGE POINT, N. Y.

IN eastern North America about thirty species of coniferous trees make up at least two thirds of the existing forest, while the remainder comprises something like 250 hardwood or broad-leaved species. About 70 per cent. of the lumber sawed in the eastern United States at the present time is of conifers or softwoods, and if the statistics for eastern Canada and for fuel, pulp-wood, cross-ties, poles, etc., were included the preponderance of softwood in the area under consideration would be still more evident. Most of the houses in the United States and Canada are built of coniferous wood, most of our paper comes from the same source, and, in all but the most densely populated regions, most of the domestic fuel.[1]

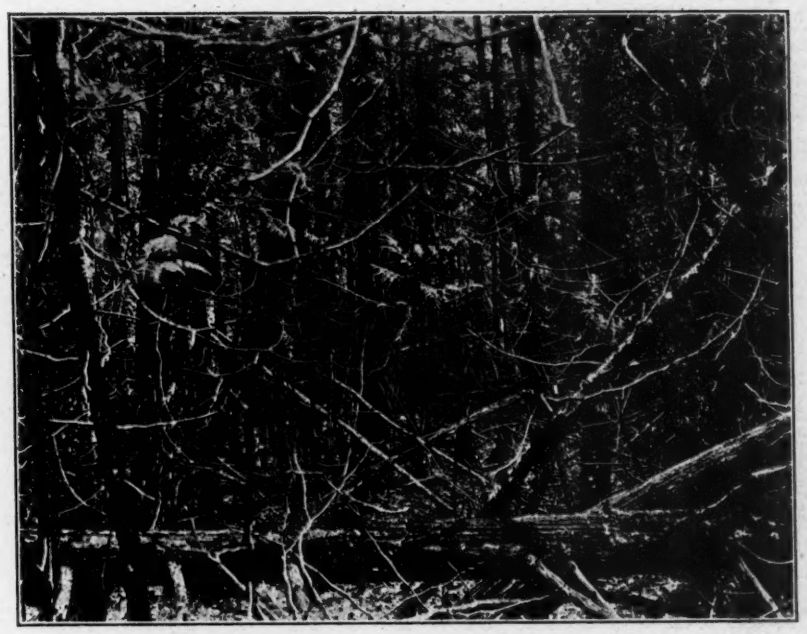
From the relative abundance and number of species it is evident that the average conifer species is represented by a much larger number of trees than the average hardwood. It happens that most of our conifers form pure stands of greater or less extent in some parts of their ranges at least, so that there are about as many types of coniferous forest as there are species of conifers. All but a few of the rarer or less important types will be described below, beginning with the northernmost, which are mainly confined to the glaciated region, and ending with those confined to the coastal plain, and one whose range extends southward into the tropics. The treatment of each type will include geographical distribution, correlations with soil, water, climate, fire,[2] etc., and notes on the economic aspects of the trees themselves and the regions in which they grow.

[1] A map between pages 488 and 489 of the 9th volume of the Tenth Census shows the distribution of coal and wood fuel in the United States three decades ago.

[2] Forest fires have generally been looked upon as regrettable accidents, and much more thought has been given to devising means to prevent them than to studying their geographical distribution and historical frequency. But those that start from natural causes seem to be just as much a part of Nature's program as rain, snow and wind (which like fire may do both good and harm at the same time), and to be subject to more or less definite laws. Their frequency, extent and effects vary greatly in different parts of the country and in different types of forests, as will be shown below, and nearly every species of conifer seems to have become accustomed or adjusted to a certain amount of fire, as to other environmental factors.

The Forest Types in Detail

The Boreal or Spruce Type.—The northernmost type of forest, which covers almost the whole of eastern North America from the arctic tundra down to latitude 45°, with many more or less isolated areas farther south, especially in the mountains, is mainly composed of jack pine (*Pinus Banksiana*), tamarack (*Larix laricina*), two or three species of spruce (*Picea*), balsam fir (*Abies balsamea*), and arbor-vitæ



Dense Growth of Spruce (*Picea Mariana*) and Arbor-vitæ (*Thuja*) in a Cold Swamp, Cheboygan Co., Michigan.. August, 1912.

or northern white cedar (*Thuja occidentalis*). In places some one of these may cover considerable areas exclusively (this is especially true of the pine), but usually two or three of them are mixed together. They have much in common in general appearance, mature trees being as a rule spindle-shaped or narrowly conical in outline, with more or less deflexed branches, and leaves an inch or less in length. The tamarack is deciduous, and the rest evergreen.

Forests of similar aspect, and made up mostly of trees of the same genera, cover large areas in all the cooler parts of the northern hemisphere. Doubtless on account of the abundance of such trees in northern Europe, where most of our Anglo-Saxon traditions originated, the spindle-shaped tree has become firmly established as the conventional type of conifer. Illustrations of these trees in their native haunts abound in publications dealing with outdoor life in the extreme north-

ern states and Canada printed since the invention of the half-tone process, about thirty years ago.

In the United States the jack pine prefers coarse sand and the other trees above mentioned are found mainly in peat bogs; but farther north they may grow in almost any kind of soil, wet or dry. (In Alaska even some of the glaciers are said to be partly covered with spruce forests.) The regions where they grow are characterized by cool and moderately humid climates, with an average temperature of 45° F. or less, and an average growing season (*i. e.*, period free from killing frosts) of not

BURNED SPRUCE SWAMP, WITH LIVING TREES IN BACKGROUND, CHEBOYGAN CO., MICHIGAN. August, 1912.

more than 150 days. The ground freezes several feet deep in winter, and temperatures of —30° F. or lower are likely to be experienced by each tree many times during its life.

The average annual precipitation is 20 inches or more, and in most places in the boreal conifer region there is more of it in summer than in winter, which tends to keep the soil moist throughout the year.

A climatic factor which involves both temperature and precipitation is the amount of snowfall; and it appears from statistics of the snowfall of the United States recently published that the type of forest under consideration can be correlated pretty closely with an average annual snowfall of 50 inches and upward. Although it would not be exactly correct from a biological standpoint to say that the narrow conical form of these trees is an adaptation to heavy snows, like the steep roofs of Norway, for example, it would be difficult to imagine any other

form of evergreen tree with the same amount of wood and foliage which would be less liable to injury from snow and ice than the spruces and balsams. The tamarack has an additional safeguard in that it loses its leaves in winter; and at the northern limit of the forests it is said to grow comparatively tall and straight while the spruces around it are much stunted.

Burned areas, in which all the trees have been killed by fires sweeping through their crowns, are and always have been, from all accounts, common throughout the spruce region (not only in the East, but also in the Rocky Mountains, where forests of different species but similar aspect predominate); and many great fires, involving loss of life and much property, have become historic.[3] In northern Michigan and doubtless in many other places where spindle-shaped conifers abound posters warning against the dangers of allowing fire to spread greet the traveler at every turn;[4] and some of the western railroads print similar advice in their time-tables.

Although at the present time the origin of most of the northern forest fires can be ascribed to human agencies, lightning is known to cause a considerable proportion of them (estimated by Plummer at 15 per cent.), and in prehistoric times it must have been the principal cause.[5] From all the evidence available it would seem that the normal frequency of fire at any one spot in the boreal conifer forests is about once in the average lifetime of a spruce tree, which may be between 50 and 75 years. The average extent of a single fire must be several square miles.

In the untold ages that fire has been a factor in the life-history of these forests there has developed a class of plants known as fireweeds, consisting of a score or more of herbs, shrubs, and short-lived deciduous trees, such as birch and aspen, which quickly take possession of burned areas and flourish until the dominant, but more slowly growing conifers have time to reestablish themselves. When the foliage of the conifers is consumed by fire the potash and other mineral nutrients stored up in several years' growth of evergreen leaves is returned to the soil in readily available form, and this must be a significant factor in the rapid growth of the fireweeds. Quite a lengthy chapter could be written about this

[3] See Pinchot's "Primer of Forestry" (U. S. Forestry Bulletin 24), Part 1, pp. 79–83, 1897; also U. S. Forestry Bulletin 117, by F. G. Plummer, 1912, especially map on page 22.

[4] Several such posters are reproduced in colors in *American Forestry* for November, 1913.

[5] See papers by Dr. Robert Bell in *Forest Leaves* for October, 1889, and the *Scottish Geographical Magazine* for June, 1897, and Bulletins 111 and 117 of the U. S. Forest Service, by F. G. Plummer, 1912. The second of Dr. Bell's papers, which is on the forests of Canada, contains much valuable information on other subjects than fire.

phenomenon, which has almost no counterpart in the coniferous forests farther south, where fires are nearly always ground-fires, and do not kill the trees outright.

The economic aspects of these northern forests are numerous and varied. The soil and climate are not very favorable for agriculture, so that the farmer, the greatest enemy of forests in this country, has done little damage, and the timber is in no immediate danger of exhaustion. The trees are used to a considerable extent for lumber, and almost as much for pulp-wood; nearly all the large paper mills in North America being located not far from such forests. Logging is nearly all carried on in winter, when the snow facilitates hauling the logs to the nearest river or railroad. The Christmas trees used in northern cities are nearly all brought from the same region. The same forests furnish our spruce gum and Canada balsam, and among them are found the most important peat deposits in North America.[6]

The boreal conifer region is a favorite resort for hunters, trappers, fishermen, berry-pickers, campers, canoeists, hay-fever sufferers, etc., most of whom migrate northward in summer from the densely populated regions a little farther south. At certain times and places mosquitoes and black-flies make life in the north woods somewhat burdensome, but the mosquitoes are at least not of the malarial variety, and poisonous snakes and some other pests are conspicuous by their absence.

The White Pine (*Pinus Strobus*) ranges from Newfoundland and Manitoba to the mountains of Georgia, and associates with many other trees, mostly hardwoods, in various parts of its range; pure stands of it being the exception rather than the rule. It grows in almost any kind of soil except the richest and poorest, wettest and driest, but seems to prefer that containing a moderate amount of humus. From its distribution we may infer that it is confined to climates where the average temperature is less than 55° F., and the growing season not more than half the length of the year: climates pretty well suited for apples but not for cotton.[7]

This species is rather sensitive to fire, at least when young, and perhaps up to middle age. In northern lower Michigan and doubtless elsewhere there are large areas said to have been covered with white pine forests up to about thirty years ago, when the lumberman came along and felled them. Since then fires, mainly of human origin, have been too frequent to allow the pine to reproduce itself except in protected places like islands and shores of lakes and streams, and the uplands are

[6] Bulletin 16 of the U. S. Bureau of Mines, by Dr. Charles A. Davis, 1911, contains a large colored map showing the distribution of peat in the United States. The Canadian deposits are still more extensive.

[7] The range of the white pine perhaps does not overlap that of the cotton crop at all, though they can be seen within a mile of each other at the western base of the Blue Ridge in northern Georgia.

covered with a worthless scrub of birch, aspen, bird cherry, and other fireweed trees, averaging about ten feet tall.

The white pine is one of the world's most important timber trees. It was originally so abundant, and its wood is so easily worked, that it has been used for almost every purpose that does not require great strength, hardness or durability. Millions of houses have been built of it, and probably hundreds of millions of dry-goods boxes. On account of its growing within easy reach of some of the oldest and most thickly settled parts of this country the value of its lumber which has been placed on the market in the last 300 years doubtless exceeds that of any other North American tree.[8] At the present time the leading states in the production of white pine lumber are Minnesota, Wisconsin, Maine, Michigan, New Hampshire, Massachusetts, New York and North Carolina, in the order named. But if the figures for the last census had been computed on a basis of equal areas, Massachusetts would rank first, New Hampshire second, and Minnesota third.

The Red or "Norway" Pine (*Pinus resinosa*) has a range approximately concentric with that of the white pine, but smaller. It is confined to the glaciated region, except that it has been reported from two or three counties in central Pennsylvania and one in West Virginia. In some places in the neighborhood of the upper Great Lakes it forms pure stands with little undergrowth,[9] something like the long-leaf pine forests of the south; but it is more commonly mixed with jack pine, white pine, or other trees. It grows in dry, usually sandy soil, nearly devoid of humus. Its climatic relations are perhaps sufficiently indicated by its distribution.

This species withstands fire almost as well as some of the southern pines to be discussed later, and it resembles them in general appearance, too. In mature trees the branches and foliage are too high up to be injured by ground fires, and the bark is thick enough to be reasonably fireproof. But even when the bark is burned through by a severe fire, making a large scar, the tree is not necessarily killed. At what age it becomes immune to brush fires has not been determined, but in the devastated pine lands of Michigan above mentioned there are many vigorous red pine saplings among the birches and aspens, as well as occasional tall trees of the same species which must have survived many fires.

The wood is so similar to that of the white pine that it is not usually

[8] For valuable notes on the economic history of this and other pines see Bulletin 99 of the U. S. Forest Service, by Hall and Maxwell, 1911.

[9] There are two illustrations of such forests in Minnesota in THE POPULAR SCIENCE MONTHLY for November, 1912 (p. 535), and another on page 10 of a report on the Wood-using industries of Minnesota published by the State Forestry Board in 1913.

distinguished in the lumber market or in the census returns. But reports on the wood-using industries of Michigan, Wisconsin and Minnesota, prepared in recent years by members of the U. S. Forest Service and published by the respective states, give the amount of each kind of wood used by manufacturers (*i. e.*, that which passes beyond the stage of rough lumber, even if it is merely planed) in each state in a year, and distinguishes between lumber cut within the state and that

YOUNG TREES OF RED PINE (*Pinus resinosa*) IN BRUSH LAND SUBJECT TO FREQUENT FIRES, CHEBOYGAN CO., MICHIGAN. August, 1912.

brought in from other states. From these we learn that the manufacturers of Michigan use in a year about 10 million feet of home-grown red pine, those of Wisconsin something over 6 million, and in Minnesota 167 million. (The corresponding figures for white pine are 70, 72 and 455; and both added together are less than half the total lumber production of the two species for these states as reported by the Tenth Census.)

The Hemlock (*Tsuga Canadensis*)[10] has a distribution very similar to that of the white pine, except that it is a little more southerly. It grows in several counties of Alabama, in which state the white pine is unknown. It commonly grows mixed with various hardwood trees and sometimes with white pine besides. It prefers moderately dry soils with considerable humus, perhaps more than any other eastern conifer. (The

[10] Also called "spruce pine" in Georgia and Alabama, if not farther north. The settlement of Spruce Pine, Ala., takes its name from this tree (see *Bull. Torrey Bot. Club*, 33: 524. 1906), and the same may be true of the place similarly named in North Carolina and even of Spruce, Ga.

states which according to the last census cut more hemlock lumber than white pine—making due allowance for the inclusion of more than one species under the same name—have richer soils, on the whole, than those in which the reverse is true.)

This tree is confined to situations rarely or never visited by fire, being protected either by the scarcity of undergrowth, or by the topography, or both. It is probably very sensitive to fire, especially when young.

Formerly the hemlock was valued chiefly as a source of tanbark, and it was once, and still is in many places, as far apart as Michigan and Georgia, a common practise to cut the trees for their bark alone, and leave the logs to rot in the woods. At present it is used largely also for lumber and pulp-wood. The leading states in the production of hemlock lumber in 1909, in proportion to area, were Pennsylvania, Wisconsin, West Virginia, Michigan, New Hampshire, Vermont, Maine, New York, Massachusetts, Connecticut, Maryland and Virginia, in the order named. (The first four of these, as well as Vermont, New York and Maryland, cut more hemlock than white pine.)

The Pitch Pine (*Pinus rigida*) ranges from New Brunswick and Ohio to the mountains of Georgia, but seems to form extensive pure

PITCH PINE (*Pinus rigida*) NEAR LAKEHURST, N. J. Typical New Jersey pine-barrens. Trees in background killed by fire. August, 1909.

stands only in southeastern Massachusetts, eastern Long Island, and southern New Jersey. Such forests usually have a dense undergrowth of two shrubby oaks (*Quercus ilicifolia* and *Q. prinoides*), with poor

sandy soils, and the ground-water level fairly constant throughout the year.

In its relations to fire the pitch pine seems to be intermediate between the spruces already mentioned and some of the southern pines. The pine-barrens of Long Island and New Jersey everywhere bear the marks of fire, which seems usually not to kill the older trees. Further studies of this point are needed.

This tree is usually too small, crooked or knotty to be of much value for lumber, but where it is abundant it has been used for many purposes, especially in the early days before transportation facilities enabled better woods to compete with it so strongly. The soil in which it grows is of little value for ordinary agriculture, but in wet places among the pines, especially in Massachusetts and New Jersey, large crops of cranberries are gathered. The pine region of New Jersey formerly produced considerable quantities of bog iron ore[11] and glass sand.[12]

The Red Cedar (*Juniperus Virginiana*) grows nearly throughout

RED CEDAR (*Juniperus Virginiana*) AND VARIOUS HARDWOOD TREES, AMONG LIMESTONE ROCKS ON MOUNTAIN SLOPE NEAR SCOTTSBORO, ALABAMA. March, 1913.

eastern North America between—but hardly overlapping—the boreal forests of high latitudes and altitudes and the tropical forests of southern Florida. It is most abundant on the northwestern flanks of the

[11] There is an interesting sketch of the old iron industry in southern New Jersey by Gifford in THE POPULAR SCIENCE MONTHLY for April, 1893.

[12] See THE POPULAR SCIENCE MONTHLY, 42: 442, 830. 1893.

Alleghanies, in what might be called the interior hardwood region, and forms nearly pure stands, commonly called cedar glades, in Middle Tennessee and northern Alabama. (Of the numerous places named Lebanon in the United States it is altogether probable that those in Ohio, Kentucky, Tennessee, Alabama and Florida, if not most of the others, were named from the presence of cedar trees, although our cedar bears little resemblance to *Cedrus Libani,* the classical cedar of Lebanon.)

The soil in which this tree grows is usually dry, and nearly always thin or rocky, but it varies greatly in chemical composition. In Alabama, Tennessee and some other parts of the country the cedar is believed to prefer calcareous soils, but this does not seem to be true throughout its range, for it grows in many places where no lime can be detected without a careful chemical analysis.

This species is very sensitive to fire, and the places frequented by it, such as pastures, fence-rows, edges of marshes, dunes, rocks, bluffs, hammocks, etc., are all pretty well protected from fire in one way or another. In fact exemption from fire seems to be the only significant character that its diverse habitats have in common, from which we may conclude that that governs its local distribution more than anything else.[13]

The wood of the cedar is very durable, but now used mostly for pencils, in which this quality is not taken advantage of. Representatives of the pencil-makers have scoured the country pretty thoroughly for it, and few large straight-grained trees have escaped them, even in small groves in the most out-of-the-way places in the South. Although it is not separated from some other species in the census returns, the cedar cut in 1909 in Tennessee (8,927,000 feet), Missouri (2,984,000 feet) and Alabama (2,869,000 feet) must be all or nearly all of this species.

The Southern White Cedar or "Juniper" (*Chamæcyparis thyoides*) is the only conifer that grows both in the glaciated region and in the coastal plain and nowhere else. It ranges from New Hampshire to Mississippi, but is not known more than 200 miles inland, or southeast of a straight line drawn from Charleston to Apalachicola (which excludes most of Florida); and there are several large gaps in its range. It usually grows in dense colonies of several hundred trees or more, much like the spruces farther north.

It is strictly a swamp tree, growing naturally only in permanently saturated soil, or peat. The water of these swamps is exceptionally free from mud, lime (perhaps also sulphur) and other mineral substances, but is usually colored dark brown by vegetable matter. Cities as far

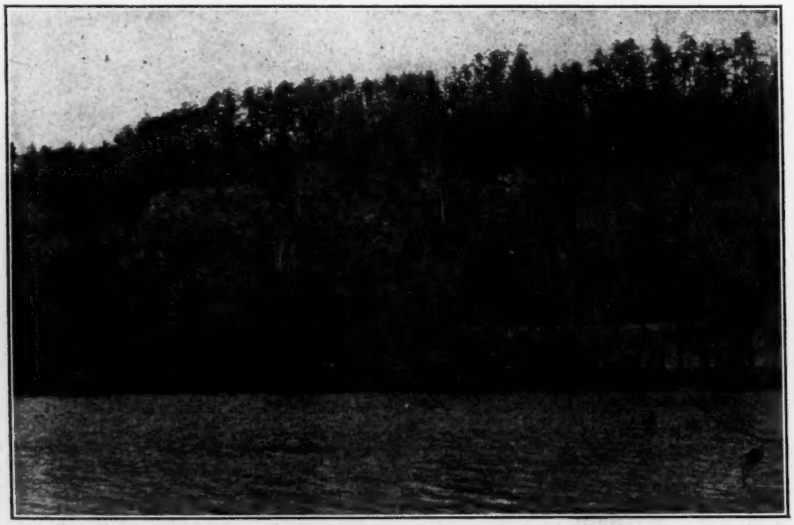
[13] This was discussed at some length in *Torreya*, 12: 145–154, July, 1912. The most complete treatise on red cedar is Bulletin 31 of the Division of Forestry of the U. S. Department of Agriculture, by Dr. Charles Mohr, 1901.

apart as Brooklyn, N. Y., and Mobile, Ala., get part of their water supply from streams in which *Chamæcyparis* grows; and the water of Dismal Swamp—one of the best-known localities for this species—used to be preferred for drinking purposes on ships sailing from Norfolk on long voyages. The manufacture of paper is an industry which seems to require good water in large quantities, and the only paper mills in the coastal plain known to the writer (viz., at Hartsville, S. C., and Moss Point, Miss.) have juniper growing in their immediate vicinity.

The relations of this species to fire have been little studied, but what evidence there is seems to indicate that they are much the same as in the case of the boreal forests already described.

The wood is very durable, and therefore used largely for poles, shingles, woodenware, etc., but it is not separated from that of arbor-vitæ and red cedar in the latest census returns.

The Scrub Pine (*Pinus Virginiana*), also known as Jersey pine, spruce pine, nigger pine, cliff pine, etc., bears considerable resemblance



Pinus Virginiana ON ROCKY BLUFFS ALONG WARRIOR RIVER, TUSCALOOSA CO., ALABAMA. March, 1911.

to the jack pine previously mentioned, but does not grow within 200 miles of it. It ranges from just south of the terminal moraine in New York and Indiana to central Alabama, nearly always forming dense groves or thickets with little admixture of other trees. It is common in the coastal plain of Virginia north of the James River, but farther south seems to be confined to the highlands. In Alabama its distribution is approximately coextensive with the coal region, where it is a familiar feature of the landscape. It grows in rather dry, poor, often rocky soil, but not quite the poorest. In Maryland and Virginia it is very common

in abandoned fields, but toward its southern limits it prefers steep rocky bluffs.

This pine, like others with very short leaves, has a thin bark and is quite sensitive to fire, though a light ground fire does not necessarily injure mature trees. In young thickets fire sometimes sweeps through the tops of the trees and kills them outright, as in the boreal conifer forests first mentioned. Its local distribution seems to be governed largely by fire, as in the case of the red cedar, for the places where it grows are usually pretty well protected by their isolation, as in abandoned fields, by topography, as on bluffs, or by the sparseness of the undergrowth.

This tree does not often grow large enough to be useful for anything but fuel, charcoal and wood-pulp.[14]

The Southern Short-leaf Pines.—Two species (*Pinus echinata* and *P. Tæda*), which although they are easily distinguished have much in common, are called short-leaf pine in the South. The latter is distinguished in the literature of botany and forestry as "loblolly pine," a name which does not seem to be used much by lumbermen and other "natives."

Pinus echinata ranges from Staten Island and southern Missouri to northern Florida and eastern Texas, ascending the mountains of

FOREST OF SHORT-LEAF PINE (*Pinus echinata*) A FEW MILES NORTHEAST OF TALLAHASSEE, FLORIDA. April, 1914.

[14] The most complete account of it available is Bulletin 94 of the U. S. Forest Service, by W. D. Sterrett, 1911.

Georgia to an altitude of about 3,000 feet, while *Pinus Tæda* grows from Cape May to Arkansas, Texas and Central Florida, rarely more than 1,000 feet above sea-level. The former grows in dry soils somewhat below the average in fertility, while the latter prefers or tolerates a little more moisture and humus. Both are usually more or less mixed with oaks and hickories, or with each other, so that opportunities for getting satisfactory photographs of them are not very numerous.

The distribution of *P. echinata* corresponds approximately with mean temperatures of 55°–70°, and *P. Tæda* with about 60°–72°. The latter does not seem to be capable of enduring temperatures much below zero (Fahrenheit). It may be regarded more appropriately than any other as the typical tree of the South. Where it abounds cotton is the principal money crop, about half the population is colored, and a large majority of the white voters are Democrats. In South Florida, where it is unknown, there are no cotton fields, few negroes, few southern traditions, and many northern people; and substantially the same might be said of the southern Appalachian region, western Texas, and several other places just outside of the range of this tree.

Both species when mature have bark thick enough to withstand any ordinary forest fire, and the dead leaves in the woods in which they grow are likely to be burned nearly every year, with little apparent injury to the trees. Trees of either species less than ten years old probably suffer somewhat from fire, though.

Both are very abundant and important timber trees, not far inferior to the long-leaf pine mentioned below, and together they are now being cut at the rate of several billion feet annually. Probably even more trees have been cut by farmers than by lumbermen, for the soil in which they grow is adapted to many staple crops. They reproduce themselves very readily in abandoned fields, though, so that they are in no immediate danger of exhaustion.

The Black Pine[15] (*Pinus serotina*), which looks very much like *P. Tæda*, but is more closely related to *P. rigida* (whose range it overlaps very little if at all), is strictly confined to the sandier parts of the coastal plain, where the summers are wetter than the winters. It is frequent from southeastern Virginia to central Florida and southeastern Alabama, but not very abundant except in eastern North Carolina, where it is the dominant and characteristic tree of the "pocosins." Its favorite habitat is sour sandy or peaty swamps, where the water-level varies little throughout the year.

Its relations to fire have not been specially investigated. Its wood is similar to that of *P. Tæda*, from which it is not usually distinguished in the lumber markets.

[15] This is the name by which it goes in Georgia. In the books it is designated as "pond pine," a rather inappropriate and perhaps wholly arbitrary name.

The Cypress (*Taxodium distichum*) is one of our most interesting trees, from several points of view, and a great deal has been written about it. It ranges from Delaware and southwestern Indiana to Florida (within two degrees of the Tropic of Cancer) and Texas, and is almost

CYPRESS (*Taxodium distichum*) WITH KNEES, IN A CREEK SWAMP, PICKENS CO., ALABAMA. Taken in early spring when trees were leafless. February, 1913.

confined to the coastal plain. It is usually abundant where it grows, but more or less associated with other deciduous trees.

This is a swamp tree, growing naturally only where the ground is alternately dry and overflowed. It can stand flooding to a depth of eight or ten feet for a few weeks at a time, and 25 feet for a few days, but does not seem to grow on the immediate banks of the Mississippi and other large rivers whose high-water periods last too long; except near their mouths where the seasonal fluctuations are necessarily less than they are farther up. Its occurrence on the banks of ox-bow lakes which were once part of the Mississippi River may therefore be used as

evidence of the minimum age of such lakes.[16] It prefers soil that is rather rich, either from the amount of mineral plant food in the strata penetrated by its roots, or from alluvium deposited by streams.

The regions where this species grows have a mean temperature of about 53°–75°, a growing season of 180 to 360 days, and an average annual rainfall of 38 to 65 inches. It is successfully cultivated, however, not only in New York or even farther north of its natural range, but at the same time in ordinary dry soil of parks and streets.[17]

The cypress swamps are pretty well protected from fire most of the time by the wetness of the soil or the absence of inflammable material on the ground, but occasionally in a very dry season fire gets into the edge of such a swamp from the neighboring uplands and kills some of the trees, whose thin bark renders them rather sensitive.

The wood of our cypress, like that of the Old World tree of quite different appearance which bore the same English name long before ours was discovered by civilized man, is very durable and easily worked, and therefore cut in large quantities for shingles and other articles which are to be exposed to the weather or placed in contact with the soil. The last census reports 955,635,000 feet of cypress as having been sawed in 1909, nearly two thirds of this amount coming from Louisiana. Next in order were Florida, Arkansas, Mississippi, South Carolina, North Carolina, Missouri and Georgia. (Some of this amount, however, possibly 10 per cent., should be credited to the other species of cypress discussed a little farther on.) The soil in which cypress is found is usually too wet for cultivation and not easily drained, so that in spite of the tree's slow growth and the rapid rate at which it is being cut the supply will probably not be exhausted for many years.

The Long-leaf Pine (*Pinus palustris*), also known as yellow or Georgia pine, extends through the coastal plain from extreme southern Virginia to the vicinity of the Caloosahatchee River in Florida and the Trinity River in Texas, and also inland to the mountains of Georgia and Alabama, nearly 2,000 feet above sea-level. (It almost meets the white pine in Georgia.) In the greater part of its range it is the most abundant tree, and there are or have been many places where it is the only tree in sight. It probably was originally, and may be even yet, the most abundant tree in eastern North America. The long-leaf pine forests, or southern pine-barrens, differ from most others in their open park-like character. Even in a virgin forest of this kind one can usually see about a quarter of a mile in every direction; and the ground is carpeted with wire-grass or other coarse grasses, or with low shrubs.

[16] See *Science*, II., 36: 760–761, November 29, 1912.

[17] In such situations its characteristic "knees," the tops of which in a state of nature seem to indicate the greatest height of water to which the tree is accustomed, are developed on a very small scale if at all.

This species grows best in poor soils, rather dry and sandy and devoid of humus, but never in the very poorest, such as sand dunes. The region covered by it has a warm-temperate climate, with very little

PARK-LIKE VIRGIN FOREST OF LONG-LEAF PINE (*Pinus palustris*), COLQUITT CO., GEORGIA. August, 1903.

snow, and more rain in summer than in winter, except in northern Georgia and Alabama.

After reaching the age of four or five years the long-leaf pine seems to withstand fire better than any other tree known, with the possible exception of one or two of its near relatives to be discussed below; and what is more, it probably could not perpetuate itself very long with-

LONG-LEAF PINE FOREST WITH ALMOST NO UNDERBRUSH, IN SOUTHERN PART OF LIBERTY CO., FLORIDA. June, 1909.

out the aid of fire. All forests of it bear the marks of frequent ground fires, which in some places come nearly every year. At the present time, of course, most of the fires are of human origin, but those set by lightning in prehistoric times could spread over much larger areas than they do now, on account of the absence of clearings, roads, and other

PURE STAND OF BLACK PINE (*Pinus serotina*) IN THE DOVER POCOSIN, JONES CO., NORTH CAROLINA. August, 19.3.

artificial barriers, so that the frequency of fire at any one spot may not be much greater now than it was originally. A fire every year during the lifetime of the tree would be likely to prevent its reproduction, but in any area that escapes burning for a few years once in fifty years or so there is opportunity for a new crop of trees.

If fire were withheld too long the oaks and other hardwoods which grow in the long-leaf pine regions would take possession of the ground and gradually crowd the pine out, for its seedlings do not thrive in shade. Proofs of this can be seen in many places in the coastal plain, where fire is barred by the topography, as on bluffs bordering swamps, or by water, as on islands and narrow-necked peninsulas. Such places, in which the soil must have been originally much the same as in the neighboring pine forests, are nearly always occupied by what is known as "hammock" vegetation, consisting mostly of hardwood trees, which make a rather dense shade and cover the ground with humus.[18]

[18] The idea that fire is essential to the long-leaf pine has been expressed long ago by a few other observers in the south, but has never been generally ac-

Few trees in the world are used by more people or in more different ways than the long-leaf pine. For strength and durability combined its wood has no superior among the pines, and it ranks equally high as a fuel. The same tree is our chief source of "naval stores" (*i. e.*, turpentine and rosin).[19] In the regions where it abounds the log cabin of the small farmer and the mansion of the wealthy lumberman or naval-stores operator are mostly built (from sills to shingles), painted, fenced and heated with the products of this tree. It supplies cross-ties, bridges, depots, cars and freight to many railroads, and motive power to some.[20] The masts, decks, and cargo of many a schooner on the Atlantic Ocean are of this species, and some of the busiest streets of our large cities have been paved with blocks of its wood in the last few years. Turpentine and lampblack from it are found in every drug-store.

As this pine grows mostly in comparatively level ground and almost unmixed with other trees, it has been cut as ruthlessly and wastefully as the northern white pine, and most of the once magnificent forests of it are now scenes of desolation. Although some other pines are mixed with it in the census returns, it is probably safe to say that at the present time the annual cut of it exceeds that of any other North American tree. Of the 2,736,756,000 feet of "yellow pine" cut in Louisiana and 1,100,840,000 feet cut in Florida in 1909 probably at least 75 per cent. was of this species.

The future prospects for it seem brighter than those of the white pine, for, as already pointed out, it is not affected much by fire, the greatest scourge of some of the northern forests. The long-leaf pine's worst enemy at present is the farmer, who in the last two or three decades has been taking possession of the once despised sandy pine lands very rapidly.[21] Notwithstanding the comparative poverty of the soil, the ease with which it can be cultivated and the mild climate are

cepted by writers on forestry, most of whom live in regions where the normal frequency of forest fires is much less. For more extended discussions of the problem see *Bull. Torrey Bot. Club*, 38: 515–525, 1911; Geol. Surv. Ala. Monog., 8: 25–27, 83, June, 1913; *Literary Digest*, 47: 208, August 9, 1913; *American Forestry*, 19: 667–669, October, 1913.

[19] The old method of extracting turpentine has been described in THE POPULAR SCIENCE MONTHLY for April, 1887, and February, 1896; and the modern cup-and-gutter method by Dr. C. H. Herty, the inventor thereof, in Bulletin 40 of the U. S. Bureau of Forestry, 1903.

[20] A generation ago pine wood seems to have been the prevailing fuel for locomotives in the coastal plain, but most of the railroads have had to abandon it on account of its growing scarcity.

[21] The "wire-grass country" of Georgia, an area of about 10,000 square miles near the center of the range of this tree, increased in population about 60 per cent. between 1890 and 1900, and 35 per cent. between 1900 and 1910, which necessitated the creation of ten new counties in that part of the state since 1904. Somewhat similar developments have been taking place in the corresponding parts of Florida, Alabama and Mississippi at the same time.

powerful attractions; and where the soil is given over to agriculture the production of timber of course stops.[22]

The Pond Cypress (*Taxodium imbricarium,* or *ascendens*) is con-

POND CYPRESS (*Taxodium ascendens*) IN VERY SHALLOW FLATWOODS POND (DRY AT THIS TIME), PASCO CO., FLORIDA. April, 1909. This species is readily distinguished from *T. distichum* by its crooked trunk and coarser bark, among other things.

fined to the coastal plain, from eastern North Carolina (perhaps as far north as the Dismal Swamp) to southern Florida (south end of the Everglades) and eastern Louisiana. It extends over 150 miles inland in the Carolinas and Georgia, but apparently not over 100 miles in Alabama or 60 miles in Mississippi. It seems to be most abundant in Georgia, where it does not form large forests, but is often the dominant

[22] For valuable information about the economic aspects of the long-leaf and several other southeastern pines see Bulletin 13 of the Division of Forestry, U. S. Department of Agriculture, by Dr. Charles Mohr (1896 and 1897).

tree over several acres, especially in Okefinokee Swamp, where it seems to attain its maximum dimensions.[23]

It grows in poor soils, usually sand, inundated part of the year, but rarely if ever to a greater depth than five or six feet. (High-water mark is indicated by the height of the enlarged base of the trunk rather than by the knees, which are less characteristically developed in this species than in *T. distichum.*) Its favorite habitats are shallow ponds which dry up in spring, and the swamps of coffee-colored (*i. e.*, not muddy) creeks and small rivers. The regions where it grows have an average temperature of 60°–75°, a growing season of 240 to 360 days, and an annual rainfall of 40 to 65 inches, over 40 per cent. of which falls in the four warmest months, June to September.

The pond cypress has a thicker bark than its better-known relative, and mature trees are practically immune to fire. The ponds in which it grows are likely to be swept in the dry season by fire, which chars the bark at the bases of the trees a little, but does no perceptible harm.

The wood is very similar to that of *T. distichum* (a little stronger and heavier, if anything), and not satisfactorily distinguished in the lumber trade, but the tree is usually too small, crooked or hollow to be worked up into lumber profitably. It is used principally for shingles, posts, poles, piles, cross-ties, etc. No statistics of its production are available, but it is evidently cut most extensively in Georgia and Florida.

The Southern Spruce Pine (*Pinus glabra*) is sometimes called white pine, or "bottom white pine," on account of its resemblance to the well-known northern tree, to which it is not very closely related, however. It ranges from southern South Carolina to central Florida and eastern Louisiana, in the coastal plain, and never forms pure stands, but associates with hardwood trees, especially the magnolia. It prefers soils well supplied with humus and protected from fire, like the white pine and hemlock, and is usually found in hammocks.

Its wood is softer than that of most other southern pines, and might be used as a substitute for white pine if it were more abundant and better known.

The Slash Pine (*Pinus Elliottii*) is also strictly confined to the coastal plain, ranging from southern South Carolina to southeastern Mississippi, inland about 165 miles in Georgia, and southward to about latitude 27° in Florida. It is sometimes the only tree on several acres, but is commonly associated with the pond cypress just mentioned, in shallow ponds or in swamps of small streams that are never muddy.[24]

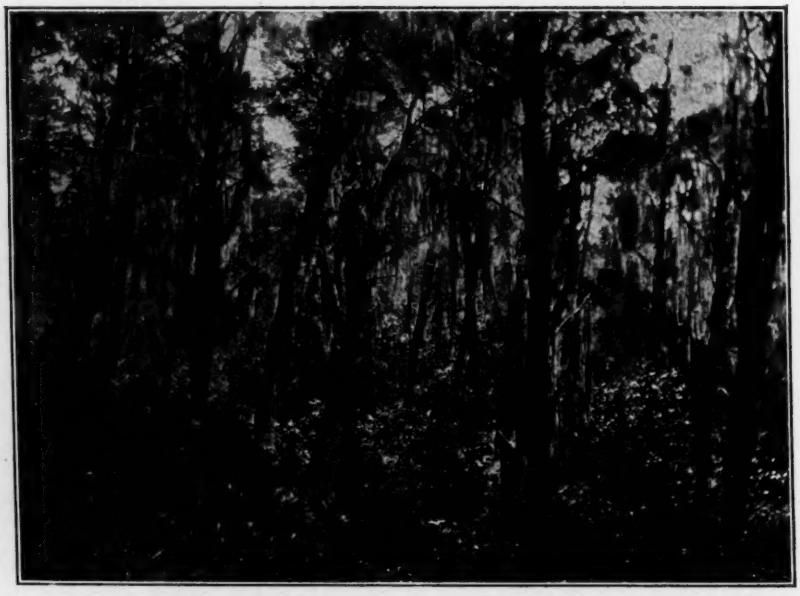
[23] See *Science*, II., 17: 508, March 27, 1903; *Bull. Torrey Bot. Club*, 32: 113, 1905; THE POPULAR SCIENCE MONTHLY, 74: 603, 604, 607, 612, June, 1909; *The Auk*, 30: 485–487, October, 1913.

[24] There is an illustration of a forest of this species in the THE POPULAR SCIENCE MONTHLY for June, 1909, p. 607.

Although it grows naturally only in saturated soil, it sometimes takes possession of comparatively dry ground from which long-leaf pine has been cut off; a circumstance which has led some uneducated people to believe that the long-leaf does not reproduce itself after lumbering, but mutates into another species. Some writers on forestry also have been misled into thinking that *P. Elliottii* is destined to take the place of *P. palustris* in the not distant future. But the range of the slash pine is much the smaller of the two, and it has shown no evidence of extending its boundaries since it was first recognized as a distinct species, about 35 years ago.

It is not injured perceptibly by fire, except when very young. Its economic properties are practically the same as those of the long-leaf pine, from which it is seldom distinguished in the lumber and naval stores markets. Its distribution corresponds approximately with that of the sea-island cotton crop, except that this cotton is not now raised west of the Chattahoochee River, while the pine extends nearly to the Pearl River.

The Florida Spruce Pine (*Pinus clausa*), a near relative of *P. Virginiana*, is the least widely distributed of all the eastern conifers, being



INTERIOR OF A FLORIDA SPRUCE PINE (*Pinus clausa*) FOREST ON A PENINSULA OF LAKE TSALA APOPKA, CITRUS CO., FLORIDA; taken from a point about twenty feet from the ground. March, 1914. The abundance of "Spanish moss" (*Tillandsia usneoides*) indicates the infrequency of fire.

almost confined to one state. It ranges from Baldwin County on the coast of Alabama to Dade County, Florida, about latitude 26°. Like the

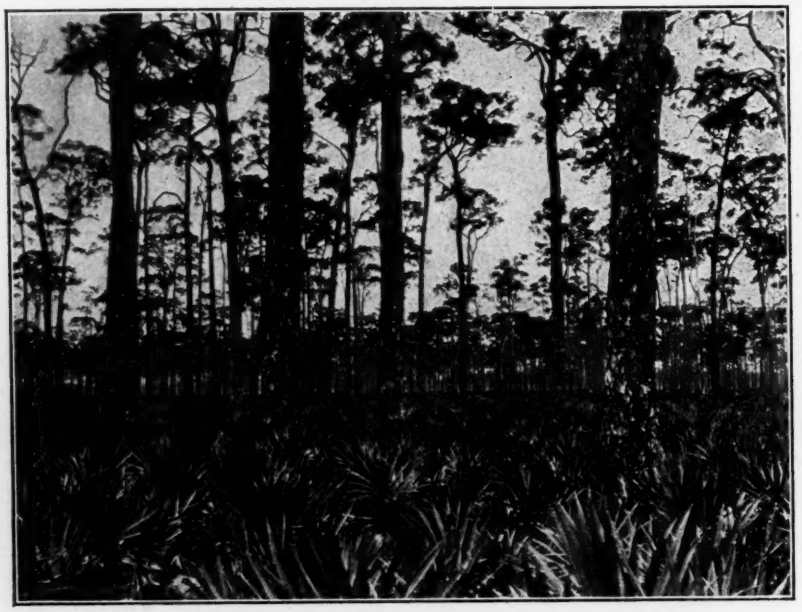
somewhat similar jack pine of the north, it is confined to the most sterile soils imaginable, where other pines are scarce or absent. Its favorite soil, about 99 per cent. white sand, is most extensively developed in the lake region of peninsular Florida, where it supports a peculiar type of vegetation known as "scrub," consisting mostly of this pine, two small evergreen oaks (*Quercus geminata* and *Q. myrtifolia*), saw-palmetto and several other evergreen shrubs, with very little herbaceous growth: grasses and leguminous plants especially being conspicuous by their

Pinus clausa IN "SCRUB," LAKE CO., FLORIDA. May, 1909.

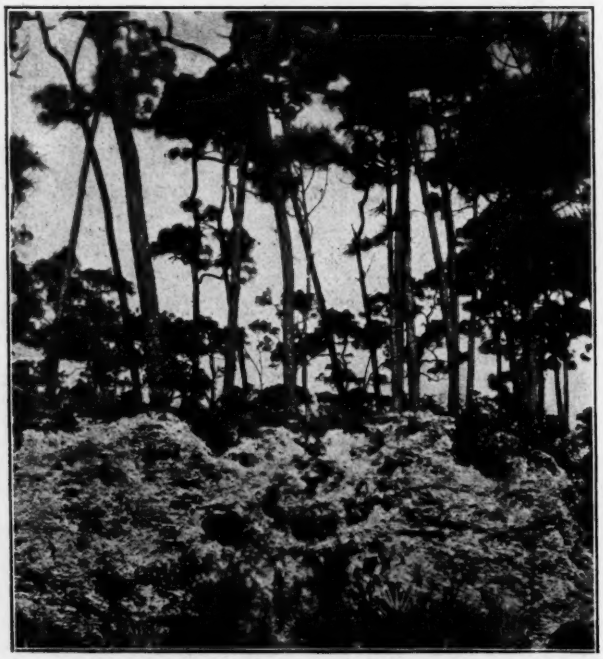
absence. Outside of the lake region this type of soil and vegetation is principally confined to old stationary dunes near the coasts.

Fire sweeps through the scrub on the average about once in the life-time of the trees, as in the boreal conifer forests, and kills the pines completely; but their cones, which normally remain closed for years, then open and discharge seeds for a new crop.

The wood of this pine is of little value, and the soil in which it grows is worthless for ordinary crops. But on the east coast of Florida south of latitude 28°, where frost is sufficiently rare to make such



PURE STAND OF *Pinus Caribaea* WITH DENSE UNDERGROWTH OF SAW-PALMETTO, NEAR PUNTA GORDA, FLORIDA. February, 1909.



Pinus Caribaea ON TOP OF A LIMESTONE CLIFF NEAR COCOANUT GROVE, DADE CO., FLORIDA. March, 1909.

ventures profitable, large areas of old dunes have been cleared of their spruce pines and planted in pineapples. The pineapple is peculiar in belonging to a family of air-plants (*Bromeliaceæ*), and taking very little nourishment from the soil.

Our southernmost conifer, *Pinus Caribæa,* seems to have no distinctive common name in general use. (It has been called "Cuban pine" by several writers on forestry in recent years, but that name would be more appropriate for *Pinus Cubensis,* a species confined to eastern Cuba.) It is abundant in South Florida, and may extend along the coast to Georgia and Mississippi, though this point has not yet been determined beyond question. It is said to occur also in the Bahamas, western Cuba, the Isle of Pines, and British Honduras. It grows in pure stands, like the long-leaf, and south of the Caloosahatchee River it is almost the only pine, and more abundant than all other trees combined. It is confined to low regions within 100 feet of sea-level, and the saw-palmetto is usually the most conspicuous feature of the undergrowth (in Florida, but not in the tropics, for this palmetto does not grow farther south).

It grows mostly in sandy soil north of Miami, and on limestone rock south of there, where sand is scarce. Although it occupies the driest soils within its range (quite unlike its near relative *P. Elliottii*), the country where it grows is so low that there is usually water within two or three feet of the surface. The climate is subtropical, with no snow and little frost, and the summers are much wetter than the winters.

This species withstands fire about as well as *P. palustris* and *P. Elliottii* do, or perhaps even better, and is exposed to it as often.

Its wood is similar to that of the long-leaf pine, except that it is more resinous and brittle, and therefore is not used much for lumber except locally where there is no other pine within easy reach. The gum does not flow readily, and consequently very little turpentine is obtained from this species; but it is not unlikely that the increasing scarcity of long-leaf pine may before long bring about the invention of some method for utilizing *P. Caribæa* as a profitable source of naval stores. The range of this species lies almost entirely south of the cotton crop, but the soil or rock in which it grows is being planted extensively to grape-fruit, mangoes, avocadoes, and other tropical fruits.

THE VALUE OF RESEARCH IN THE DEVELOPMENT OF NATIONAL HEALTH[1]

By Professor BENJAMIN MOORE, M.A., D.Sc., F.R.S.
UNIVERSITY COLLEGE, LIVERPOOL

THE history of medical science presents to the curious student a remarkable development commencing in the latter half of the nineteenth century, and one worthy of special study, both on account of the light that it sheds on the present position and the illumination it affords for future progress.

If any text-book of medicine or treatise on any branch of medical science written before 1850 be taken up at random its pages will reveal that it differs but little from one written a full century earlier. If such a volume be compared with one written thirty-five years later, it will be found that the whole outlook and aspect of medicine have changed within a generation.

Erroneous introspective dreams as to the nature of diseases as "idiopathic" as the many strange maladies which their authors are so fond of describing have been replaced by fast-proven facts and medicine has passed from an occult craft into an exact science based upon experimental inquiry and logical deduction from observation.

What caused this rapid spring of growth after the long latent period of centuries, and are we now reaching the end of the new era in medicine, or do fresh discoveries still await the patient experimentalist with a trained imagination who knows both how to dream and how to test his dreams?

It is but a crude comparison that represents the earlier age as one of empiricism and imagination, and the later period as one of induction and experiment. Empiricism has always been of high value in science, it will ever remain so, and some of the richest discoveries in science have arisen empirically.

Imagination also is as essential to the highest scientific work to-day as it was a century ago, and throughout all time the work of the genius is characterized in all spheres of human endeavor by the breadth and flight of the imagination which it shows. The great scientist, whether he be a mathematician, a physicist, a chemist, or a physiologist, requires imagination to pierce forward into the unknown, just as truly as does the great poet or artist. Also, the inspired work of poet or painter must be concordant with a system of facts or conventions, and not outrage

[1] Address of the president to the Physiological Section of the British Association for the Advancement of Science, Australia, 1914.

certain canons of his art, as certainly as the true and lasting work of the scientist must accurately accord with natural laws.

The scientist is as little able to prove the fundamental truth or existence of the groundwork upon which modern physical, chemical and physiological theories are built, as the artist is to prove the ethics, or perfect truth, or perfect beauty, of those conventions upon which poetry, painting or that great group of studies termed the "humanities" find their basis. But the artist or philosopher knows that, using these conventions as the best at present discovered, he can produce works of which the beauty and consistency appeal to all educated human minds capable of appreciation. Similarly, the conventions of natural science, properly understood, appeal to the imagination of the scientist, call forth new ideas to his mind, and suggest fresh experiments to test those ideas; or, a chance empirical observation of an experimental nature, which without theory and scientific imagination would remain isolated and sterile, placed in relationship to the rest of the scheme of science, awakens thought, and may lead to a fresh departure and a long train of important discoveries.

It was this correlation of the imagination with experimentation and the tracing out of relationship from point to point so as to develop the evolution of phenomena that characterized the science of medicine when new-born about seventy years ago and differentiated it from the older nosological medicine in which imagination and experimentation, while both existing, seemed to possess independent existences and pay little regard the one to the other.

It seems well-nigh forgotten nowadays by the majority of people that science and religion originally began together from a common thirst for knowledge, and usually in the same type of mind endowed with a divine curiosity to know more of the origin and nature of things.

Every great religion worthy of the name contains some account of the natural history and creation of the world, in addition to its metaphysical aspects, and reflects the degree of knowledge of natural science possessed by the nation in which it arose at the time of its birth.

The fundamental error throughout the ages of human conceptions, both in science and religion, was that of a non-progressive world to which a stereotyped religion, or science, could be adapted for all time. Perfection was imagined where perfection, we are now happy to realize, was impossible, and, believing in this imaginary perfection and that all things new deviating from it were damnable men were prepared to burn one another at the stake rather than allow error to creep into the world in either science or religion. Thus there have been martyrs for the scientific conscience just as for religious belief, and at this distance in time we can perhaps better understand both inquisitor and martyr and realize that both were fighting for great ideals.

Evolution has taught us that as knowledge broadens we must be pre-

pared to have wider vision and abandon old theories and beliefs in the new-born light that makes the world better to-day than it was yesterday, and that also will show things up to our mental vision more clearly to-morrow than they stand out to-day. To the members of any great craft, or profession, or religious order, this scientific outlook which accepts as fundamental a progressive world and insists that its votaries should adapt their lives to such a doctrine, is peculiarly difficult of assimilation. Routine fixes all men, and so when any new discovery appears to demand change from that order to which the mind has become accustomed, it is immediately looked upon with suspicion, and there being little plasticity of mind remaining, it is rejected as heretical or revolutionary after but scanty critical examination. The cry of the craft in danger has been used efficaciously on many occasions since the days of the Ephesian silversmiths, nor is such a cry at once to be set down to pure selfishness. A craft is often worth preserving long after the forces which have called it into being have commenced to slumber, and conservatism of this type is at times an important factor in social progress. However, there are certain limits which must not be surpassed, room must be made by adaptation for the new knowledge, or it will establish a craft of its own iconoclastic to much worth preserving in the older system.

It is important to insist upon these limitations, because a too reactionary spirit abroad in medicine between 1860 and 1880 prevented the world from benefiting from those remarkable discoveries by Pasteur and their proposed applications by Lister, which laid the foundations of modern medicine and modern surgery. These pioneers of the new age in medical science had to wage for many years a stern and bitter fight against the strong forces of ignorance and prejudice. But for this illogical resistance by men who would not even test the new discoveries, and instead spent their time in sneering at the new geniuses who had leadership to give the world, France and Germany would have been saved many thousands of brave lives in the great war of 1870–71. Even thereafter, the slow struggle continued of the few who knew against the many who refused to be taught, and a perusal of any orthodox text-book of medicine published between 1875–80—that is, more than a decade after Pasteur's great discovery—will show that the etiology of scarcely a single infectious disease had become known, and that medical science was, for example, as ignorant of the nature of tuberculosis as we are to-day of the nature of carcinoma. Take, as an example, the following quotation from a well-known text-book of the theory and practise of medicine published in 1876: "It is now, however, generally admitted that tubercle is no mere deposit, but, on the contrary, a living growth as much as sarcoma and carcinoma are living growths." The tubercles were the only initial lesion observed, the infecting organism was entirely unknown, and the pathologists of this comparatively re-

cent date argued at length as to whether tubercles were to be classed as "adenomata" or were something *sui generis*.

There is a gleam of sunlight for the future in this retrospect at the ignorance of the past, for, if men were as ignorant regarding tuberculosis thirty-eight years ago as to-day they are about cancer, then it may be argued that a generation hence as much may be known about cancer as is known now about tuberculosis.

It is particularly important at the present moment, when so much interest is being taken in national health, to point out the urgent necessity of allowing as little lagging behind as possible to ensue between the making of discoveries and the practical application of the results by organized national effort for the well-being of the whole community.

It must sadly be admitted that it is craftsmanship in imaginary danger fighting hard for the old methods unchanged which were in vogue fifty years ago, that stands most prominently in the way of advance. As great a harvest as that which followed the application of the principle of antisepsis in surgery awaits the application of the self-same principle in national sanitation to-day, but the very profession which ought to be urging forward the new era apparently stands in dread of it, and seems to prefer to reap its harvest from disease rather than to seize the noble heritage won for it by the research of pioneers and so stand forth to the world as the ministry of health. Fortunately it can not be, the bourne has been passed, and there is no going backward. The advances that have already been made have awakened statesmen and people alike to the needs of the situation, and all have resolved to be disease-ridden no longer. The laws of health must be made known to the people at large, and schemes laid before them for a national organization for the elimination of disease. Disease is no longer an affair of the medical profession, it is a national concern of vital importance. The problem is not a class question, all humanity stands face to face with it now in the light of modern research as it never has faced it before. It has been realized that disease never can be conquered by private bargains for fees between individual patient and individual doctor. Research into diseases of unknown causation can not be subsidized upon such individualistic lines, and in the case of diseases of known etiology and modes of propagation the passage of disease from individual to individual can not be controlled by such private methods as that of the afflicted individual subsidizing the doctor for his own protection. Cost what it may, a healthy environment must be produced for the whole mass of the population, and the laws of physiology and hygiene must be taught not only to medical students, but to every child in every school in the country. People can not live healthy lives in ignorance of the fundamental laws of health merely by paying casual visits to physicians, and no one class in the community can be healthy until all classes are healthy.

The problem of national health is one of peculiar interest to physiologists, and to the exponents of those experimental branches of medical science which have sprung from the loins of physiology, for it was with them that the new science of medicine of the last fifty years arose, and they ought to be the leaders of the world in this most important of all mundane problems.

It is well worth while to consider our opportunities and responsibilities and raise the question whether our present system and organization are the most suitable for attaining one of the most sublime ambitions that ever appealed to any profession. By definition, our science studies the laws of health and the functions of the healthy body, therefore, it is ours to lead in the quest for health. Is this object best achieved if we confine ourselves to research in our laboratories, and to the teaching of the principles of physiology to medical students, while we leave the community as a whole uninstructed as to the objects of our research and its value to every man, and trust the medical students whom we turn out to communicate, or not communicate as they choose, the results of their training and our research to the world at large?

There is little question that much of the ignorance abroad in the world, and much of the fatuous opposition to our experimental work and research, arise from this aloofness of ours. Here also lies the cause of much of the latent period in the application of acquired knowledge to great sociological problems, and the presence of untold sickness and death which could be easily prevented if only a scientific system of dealing with disease could be evolved.

The position occupied by scientists in medicine at the present day is largely that of schoolmasters to a medical guild, and even at that, one constructed upon lines which have grown antiquated by the progress of medical science. It ought now to become the function of the scientist to remodel the whole system so as to fight disease at its source. The whole situation at the moment calls out for such a movement. On the one hand, there exists a widespread interest on the part of an awakened community in health questions, evidenced by recent legislation dealing with the health of school-children, with the health of the worker, with the sanitary condition of workshops, with the questions of maternity and infant mortality and with the communication of infectious diseases. On the other hand, there is chaos in the medical organization to meet all these new demands, and the ample means recently placed at the command of the nation and of municipal authorities are being largely wasted by overlapping and misdirection for lack of skilled leadership. Surely it is a time when those who have laid the scientific foundations for the new advances should take counsel together, assume some generalship, and show how the combat is to be waged, not as a guerilla warfare, but as an organized and coordinated campaign.

There are two essentials in the inception of this organized campaign against disease on a scientific basis. The first is to demonstrate clearly to the public mind that modern scientific medicine arose from the experimental or research method, that it was only when experimental observation of the laws of health and disease, in animals and man, commenced on an organized and broadcast basis that medicine and surgery leaped forward and the remarkable achievements of the past fifty years began. Also that it is only by the organization and endowment of medical research that future discovery and advancement are possible. The second essential is to convince the public that a national system must be evolved placing medical science and medical practise in coordination, so that the discoveries of science may be adequately applied in an organized scheme for the prevention and treatment of disease. The method in which discoveries have been made in the past suggests an amplification and organization along similar lines for the future, and the banishment of many diseases by public health work in the past suggests that it is more efficiently organized and widespread public health work in the future, extended from the physical environment to the infecting individual, that will be most fruitful in banishing other diseases.

If it be queried by any one here, what has physiology to do with disease, it may be replied that the question comes at least fifty years too late. The methods evolved first by physiologists in experimentation upon animals have become the methods of all the exact sciences in medicine. Bacteriology is the physiology of the bacterium, and the study of protozoan diseases the physiology of certain groups of protozoa. Organo-therapy had its origin in physiology, and many of its most brilliant discoveries were made by physiologists, and all by scientists who used physiological methods. Serum therapy, experimental pharmacology, and the great problems of immunity all arose from the labors of men with expert training in physiology who branched out into practical applications achieved by the extension of the experimental, or research, method. The modern methods of medical diagnosis and the brilliant technique of contemporary surgery, what has opened the door to these but the experimental method? From the days of the first successful abdominal operation to the present day research in laboratory or in the operating theater has pioneered the way, and the sooner this simple truth is known to all men the better for medical science. Every time any surgeon first tries a new operation there is in it an element of experiment and research of which the ethical limits are well-known and definable, and any person who logically thinks the matter out must see that it is the research method which has placed the science and art of surgery where it stands to-day. Exactly the same thesis holds for medicine. How could any physician predict for the first time, before he had tried it experimentally on animal or man, the action of any new drug, the effect of any variation in dosage, the result of any dietary, of

the employment of any course of physical or chemical treatment, or of anything in the whole of his armamentarium? Yet the public are rarely told any of these wholesale truths but are rather left to speculate that each medical and surgical fact sprang forth as a kind of revelation in the inner consciousness of some past genius in medicine or surgery, who, in some occult way, knew of his own certain foreknowledge what would be the definite effect of some remedy or course of treatment before he tried it for the first time on a patient, or perhaps had the ethical conscience and genuine humanity to test it on a lower animal before he administered it to man.

It may, in short, be taken as an axiom of medical science that everything of value in medicine and surgery has arisen from the applications of experimental research. Nor can future advance be made by any other method than the research method. It is true that accident may teach occasionally, as it did, for example, in the dreadful burns unwittingly inflicted on themselves and patients by the early experimenters in X-ray therapy and diagnosis. But accident is only the most blundering type of experimentation, and results obtained by its chance agency do not really invalidate the universal law that man only learns by experience or, in other words, by research. Research is, after all, only the acquisition of fresh experience by the trained expert, usually led on to his experiment by inductance from other known facts.

It has been said above that all that is valuable in medical science has been acquired by research; the converse may now be pointed out, that much that was valueless, dangerous, and even disgusting in medicine in earlier days was incorporated into the medical lore of the time and often remained there for generations stealing lives by thousands because physicians had not yet adopted the research method, and so based their practise upon ignorant and unfounded convention. It is noticeable in literature that up to somewhere in the beginning of the nineteenth century physicians and surgeons were often as a class looked upon by scholars and educated people with a certain amount of contempt. There were notable and fine exceptions in all ages, but, taken as a whole, the profession of medicine was not held in that high esteem and admiration that it is amongst all classes to-day. Take, for example, Burns's picture of Dr. Hornbook or Sterne's account of Dr. Slop in "Tristram Shandy," and similar examples in plenty are to be found in the Continental literature. The reason for the change is to be found in the comparative growth of medical science as a result of the research method. The physicians of those days were very often ignorant quacks employing the most disgusting and dangerous remedies, or methods of treatment, based upon no experimental knowledge and handed own in false tradition from ignorant master to ignorant and often almost illiterate apprentice. It is only necessary to peruse the volumes written

on materia medica of this period to shudder at the nature of the remedies apparently in common use; the details are unfit for modern publication.

Even in the first half of the nineteenth century patients were extensively bled almost to exhaustion in a vast variety of diseases in which we now know with certainty that life would be endangered by such treatment and chance of recovery diminished. Thus, in a text-book published in 1844 by the professor of medicine in the most famous university in medicine of our country, and a physician in ordinary to her Majesty Queen Victoria, it is said that in the treatment of pneumonia

> the utmost confidence may be placed in general Blood-letting which should always be large and must almost always be repeated sometimes four or six times or even oftener. Blistering and purging, under the same cautions as in the Bronchitis, are to be employed; and two other remedies have been much recommended—Opium, especially combined with Calomel, and the Solution of Tartar Emetic.

It seems scarcely creditable to us nowadays that about this same period a low diet, blood-letting, emetics and purgatives were employed as a treatment in phthisis, yet such is the case. It is in keeping with the above, and in strange contrast to modern treatment, to find it recommended that if the patient can not winter abroad he is ordered "strict confinement within doors in an artificial climate, as near as possible to 60° Fahr., during at least six months of the year in Britain." From the text-books of medicine of this period, only seventy years back, instances of wrongful and even dangerous treatment in most of the important diseases might be produced. There is no basis of accurate scientific knowledge of physiology, biochemistry or bacteriology underlying the visionary notions about disease. The real causes of the diseases being obscure, they are commonly set down to so-called diatheses or habits such as the "hæmorrhagic diathesis" or the "scrophulous habit." Also, the action of infective organisms and the intimate relationships in regard to infection of members of the same family being unknown or forgotten, such "habits" are erroneously set down as hereditary. When there is no other channel of escape the word "idiopathic" is coined to cover the ignorance of the learned.

If now we pass onwards about thirty years in time, halving the distance between the above period and our own time, and consult an important text-book of medicine published in 1876 by a Fellow of the Royal College of Physicians, a physician and lecturer at a famous London Medical School, and a lecturer on pathology and physiology, we find that the progress attained by research in physiology, and physiological chemistry, and a growing belief in the possibility of infection in many diseases by the microorganisms, now demonstrated so clearly in certain cases by Pasteur and his followers, have commenced to do their beneficent work in medical practise. The heroic bleedings and leech-

ings and the scarcely less violent druggings with strong drugs have disappeared. The patient is less harassed by his doctor, who is more content to assist the natural processes of recuperation as his knowledge of applied physiology and hygiene teach him, rather than to thwart them and to lessen resistance as his predecessor often did a generation ago when he knew no physiology and less hygiene. Still, the comparison between the text-book of even forty years ago and one of the present day shows a wonderful advance, all flowing from the use of the research method in the intervening years, both in knowledge of the origins and in the treatments of the diseases.

Time and space forbid going into details, but the whole of serum, vaccine and organo-therapy were unknown, with the single exception of vaccination for variola. Enteric fever has been separated from typhus, but its etiology is still obscure, and, to a large extent as a consequence, the mortality from it is fifteen to sixteen per cent., or quadruple present-day figures, and it is one of the commonest of diseases. The cause of diphtheria is unknown, although it is now recognized as a "contagious" disease, and as yet research in bacteriology has supplied no cure for it. The unity of the various forms of tuberculosis is unsuspected, the infecting organism is unknown, and, as a result, it is not even recognized as an infectious disease and heredity figures most strongly in a dubious etiology leading up to a vacillating treatment. Pneumonia is not recognized as due to a microorganism, and is described as one of the "idiopathic" diseases. The cause of syphilis, and its relationship to *tabes dorsalis,* and general paralysis are unknown, and generally it may be said that the causes of disease are either entirely unknown or erroneously given in at least three quarters of the very incomplete list of diseases that are classified and described.

This, after all the centuries, was the doleful position of medical science in the year 1876, when suddenly light began to shine upon it, brought not by the agency of any member of the medical profession, but by a physiological chemist, and he was led to his great discovery, not in an attempt to solve some problem of practical medicine, but by scientific observations devoted to an apparently purely philosophical critical research into the supposed origin of life in a particular way.

It was the experimental or research method in biochemistry supported by physiological experiments on animals which in the hands of Louis Pasteur laid the foundations of true knowledge, and transformed medicine from what has been described above into the glorious, living, evolving science that we possess to-day.

The men who fought side by side with Pasteur in his famous struggle against orthodoxy in medicine as represented by the leading physicians and surgeons of the period between 1860 and 1880 were mainly chemists, biologists and physiologists, such as Claude Bernard, Paul Bert, J. B. Dumas, Biot, Belard and Sainte-Claire Deville, in his

own country, and Tyndall and Huxley in ours. A few physicians and surgeons of scientific training in France and England recognized the importance of his discoveries, such as Alphonse Guérin, Villemin and Vulpin, in his own country, while Lister in ours was already at work, had experimented widely and wrote his memorable letter of congratulation to Pasteur in 1874, informing him of the work he had been doing in introducing antiseptic surgery in England during the preceding nine years. Against this intrepid little band of experimental scientists were massed all the batteries of orthodox medical nescience served by the distinguished physicians and surgeons of the time; but truth is mighty and must prevail. Davaine applying Pasteur's principles in a medical direction had found out the bacterial origin of anthrax, and although he was violently attacked by oratorical arguments in opposition to experimental proofs, and accused, as many physiologists are to-day of having "destroyed very many animals and saved very few human beings," his facts held fast, and combined with the later experiments of Koch and of Pasteur, not merely established the etiology of anthrax as we know it to-day, but gave a support and forward growth to that newborn babe, Bacteriology, which without such animal experiments could never have grown into the beneficent giant that it is to-day in all its glorious strength for the weal of humanity.

Pasteur himself meanwhile was hard at work in the small ill-equipped laboratory of physiological chemistry of the Ecole Normale at Paris from which the fame of his discoveries began rapidly to spread and shed a new light forth on the medical world. Pasteur at this stage had already largely rehabilitated the national prosperity of his own country by his successful researches on silk-worm disease and on fermentation maladies and the diseases of wines. All this effect upon national industries, it is to be noted, followed on from an inquiry of apparently no practical importance on spontaneous generation. He now turned his genius towards disease, there also utilizing the same discovery arising from a research that contained at first sight no possible applications to disease and the remainder of his life was devoted to the extension of these studies. The subsequent history of this discovery is the science of bacteriology with all its ramifications and manifold applications in industry, in agriculture, in medicine and in public health, investigated by the experimental method by thousands of willing workers all over the civilized world. Who but the ignorant Philistine, who knows not what he prates about, can deny the profound influence of animal experimentation, and the philosophic application of the principle of research upon the history of the world?

Let us now, from the vantage-point of the present, look back at the past and glean from the study of the manner in which this science took origin some knowledge to guide us, first, as to how research may be

fostered and encouraged in the future, and secondly, as to how the results of research may be applied for social advantage.

The first and perhaps the finest thought of all is that research must be pursued with the highest ideals of the imaginative mind apart from all desired applications or all wished for material advantages. If we might personify nature, it would seem that she does not love that researcher who only seeks her cupboard, and never shows her finest treasures to him. She must be loved for her own beauty and not for her fortune, or she will ne'er be woed and won. Not even the altruistic appeal of love for suffering mankind would seem to reach her ears; she seem to say: "Love me, be intimate with me, search me out in my secret ways, and in addition to the rapture that will fill your soul at some new beauty of mine that you have discovered and known first of all men, all these other material things will be added, and then I may take compassion on your purblind brothers and allow you to show them these secret charms of mine also, so that their eyes may perchance grow strong, and they, too, led hither by you, may worship at the shrine of my matchless beauty." By all the master's discoveries in all the paths of science, Nature is ever teaching us this great doctrine to which we have closed our ears so long. She tells us the creation of the world is not finished, the creation of the world is going on, and I am calling upon you to take a part in this creation. Never mind that you can not see the whole, love that you see, work at it, and be thankful that I have given you a part to play with so much pleasure in it, and so doing you will rise to the highest ideal.

This is religion with thirst for knowledge as its central spring; does it differ much from those aspirations which have made men of all nations worship throughout all the ages? Anthropology teaches us that the religious system of a race of men gives a key to their advancement in civilization. If this be so, growth in natural knowledge must elevate our highest conceptions, furnish purer ideals and give us more of that real religion that is to be found running so strongly in the minds of great individuals such as Isaac Newton, Michael Faraday, Louis Pasteur, Auguste Comte. A great man may be strongly opposed to the orthodox creeds of his day, he may even sneer at them, he may be burnt at the stake by their votaries, and yet be a man of strong religious feelings and emotions which have furnished the unseen motive power, perhaps unsuspected even by himself, that leads to a whole life of scientific heroism and enthusiasm.

The practical lesson for us to learn from all this is that we must consider research as sacred and leave it untrammelled by fetters of utilitarianism. The researcher in functional biology, for example, must be left free to pursue investigations as inspiration leads him on any living structure from a unicellular plant to a man, and must not be expected

to devise a cure for tuberculosis or cancer. In his research he must think of something higher even than saving life or promoting health, or he is likely to prove a failure at the lower level also.

As an example of the wrong attitude of mind towards science, there may be taken the point of view of those utilitarians who complain of the amount of time and discussion at present being given to the problem of the origin of life. These wiseacres with limitations to their brains say "that it is an insoluble problem, we shall never get to the bottom of it, let us simply assume, since it is here, that life did originate somehow, and, taking this as an axiom, proceed to some practical experimental problem; the origination of life does not lend itself to experimental inquiry."

Now it is, strange to say, just those problems that appear most insoluble upon which the inquiring type of mind loves to linger and spend its energies, and, although the problems never may be solved, the misty solitudes to which they lead are glorious and the fitful gleams of half-sunshine that come through are more kindling to the senses of such men than the brightest sunshine on the barest of hills. It is here, and in such quests, that the biggest of human discoveries are made and not all of them are in natural science alone.

The search after the mystery and origin of life had profound influence in raising man from a savage to a civilized human being, and is found as an integral part in all religions above a certain level of savagery. Much of the system of morals and ethics of civilized nations is unconsciously grouped round this problem, and we owe the existence of that social conscience which makes each of us our race's keeper to our interest in the nature of life, and our ties with other lives. Leave such a problem alone and attend to routine researches! Why, the human intellect can not do it, such problems compel attention! What, it may be asked, was it that started all this routine research in biology, in favor of which we are asked to abandon the search after the origin of life? The routine research would not exist, but for a discovery made in investigating whether life originated in a certain alleged way.

If the whole science of bacteriology emerged from a proof that a certain alley did not lead to the origin of life, how much more glorious may that knowledge become that finally leads us to this goal, or even one step onward in our true path towards it. The search after the origin of life is an experimental inquiry, it leads straight to research, that is all the physicist or chemist demands of a theory, it should be enough for the biologist. We who search for this are not occultists whatever may be said of those who oppose.

Let us then learn to have a catholic spirit about research, and try to convince the world that it commands devotion not merely because of material advantages which it may bring, but because it is the most

lovely and most holy thing that has been given to man. So may we clear the fair name of science of the false charge of materialism that is so often brought against it by those who do not know and judge science purely by mechanical inventions.

Next let us consider the applications of scientific discovery and see if we cherish aright the gifts of the fairy godmother, for her gifts are dangerous if wrongly used. Consider, if this be doubted, the enormous advantages given by mechanical and chemical contrivances in producing the material comforts necessary to civilized human existence, and then turn your eyes to the reeking slums of our great cities. It is clear that natural science can not go on successfully alone, it must take sociology with it if our world is to be a better world to live in because of the gifts brought by scientific discovery.

Nor is the ideal and the outlook different in the least from that given above for pure research, when we come to consider its applications, the same high spirit must prevail in all our endeavors, or we shall defeat our own ends and miserably fail. Selfishness here, as everywhere, must recoil on the culprit, who only deadens his own soul. Health is needed not to grow wealthy or to prolong to greater length a "lingering death" as Plato puts it, but to fill life with happiness, and beckon the bold and adventurous forward to higher things. Here we must copy Nature's own plan and take care of the race as a whole instead of spending our energies upon single individuals or favored classes. Nor need any one fear that any individual or any particular class in the community is going to suffer from the adoption of the true scientific attitude towards disease. The penalty taken by nature on the more comfortable classes who have hitherto enjoyed the greater share in government for allowing the existence of poverty, disease and slumdom, is to utilize this negelected area as a culture-ground for diseases, which invade the classes above. Nature is still at work creating, still conducting evolution at the highest level, and disease is at present the tool with which she is working. So long as those poverty-stricken slums are allowed to remain, just so long is she grimly prepared to take her toll of death and suffering from those who ought to know how to lead on and do it not. The disease and the crime below are to the social community what pain is to the individual, and just as the special senses become more highly organized and sensitive as the nervous system becomes more highly developed, so as the civilization of the community intensifies does the public conscience awaken to forms of mischief and crime in one generation that were unsuspected in a previous one. So social evils become intolerable and finally are removed. How then are we employing our knowledge as to the causation of disease to the public problem of its removal or abatement?

In regard to the physical environment much has been done during

the past generation towards applying the laws of hygiene, as is shown in the sanitation of our great cities, and especially in regard to the question of water-supply. It is good, for example, that Glasgow goes to Loch Katrine for her water-supply, Manchester to the English lakes, and Liverpool to the Welsh hills. Each of these great cities carries for many miles the pure distillate of the hills to its million of inhabitants. It has cost much in pounds sterling, though not more than if each family had a pump in its backyard. On the other hand, think of the disease and suffering and death prevented, enteric fever almost gone where thousands would have died of it, and tens of thousands been debilitated, and these of the best of the citizens, for disease is no eliminator of the unfit. Think of all this, and then say, Did it not pay these great cities to bring the pure water from the lakes in the hills?

But why do these good cities content themselves to allow their little children at a most susceptible age to be supplied still with milk which contains the bacillus of tuberculosis in so large a percentage as five to ten per cent.? And why does the law of the land prevent these corporations from searching out tubercular cows in all the areas supplying them with milk? If it is part of the business of a municipality to see that its citizens have a pure water-supply, why should it not also be allowed to see that they have a clean milk supply?

Long ago the power to make the lame to walk was regarded as a divine gift. When is mankind going to awake to the fact that science has placed this gift in its hands? Much more than half of the lame and spinally-deformed children in our midst are in that condition because of infection of joints or spine with the bacillus of tuberculosis. By open-air hospitals and open-air schools we seek and succeed in curing a percentage of them, but how much better it would be if we took the fundamental problem of tubercular infection in hand and prevented them from becoming lame and deformed?

There is at present on foot in England a great scheme to enable the blind to read, and it deserves our support because it is our fault that these people are blind. The sad fate of the man born blind appeals to all kind hearts; but men are not born blind, they become blind within a week or two of birth because of an infectious disease contracted from the mother at birth. Science knows and has taught the world how this blindness can be quite prevented, and it is because of our faulty organization for attending to maternities amongst the poor that these people are blind. By proper organization practically all blindness arising at the time of birth can be prevented. Why is it not done? Thus our modern science can make the blind to see and the lame to walk, but it is so manacled by ancient ways and customs that it is left powerless, and so there are these maimed and darkened lives of innocent people, and they are left partially burdening the community which has only its own folly to blame for the whole stupid position.

Let us consider lastly a disease which collects the last toll from one seventh of humanity, and debilitates and enfeebles the lives of many whom it does not entirely destroy. At all ages, in infancy, in the prime of life, and in life's decline, it snatches away the best of our fellowmen. How are we organizing our campaign against tuberculosis? Bacteriology has taught us that it is an infectious disease and has isolated the organism. It is an undoubted fact, proven to the hilt by many inquiries and observations, that infection passes from individual to individual. How is this knowledge being applied, and how are we attempting to stem the tide of infection? In the United Kingdom alone about 70,000 persons die annually of the disease, and all over the civilized world the total death roll of human kind annually from tuberculosis probably does not fall short of a million souls. This tide of infection is kept up, year in, year out, and every 70,000 dying annually in Britain must have infected 70,000 fresh victims before they themselves are carried away. Can it not be stopped, this foul tide of infection? What is being done to stop it? Sanatoria are being provided for the early cases, the bad and most infectious cases are largely being left alone to sow infection broadcast and then die. This is the chief means being used at present to stop the tide. The early non-infectious case is deemed the more important to look after, and the well-advanced, open, thoroughly infectious case is left to itself to infect others and then to die. This is the condition of our public health attitude in regard to tuberculosis. It is a travesty on the application of all biological laws, and in direct opposition to all laws of racial preservation. Industrial conditions have produced an artificial environment and enhanced the chances of infection by the organism of this disease; it should be our plan to copy nature's method and safeguard the interests of the community, and to do this we must proceed on the plan of separating the source of infection —that is to say, the infectious individual from the sound individual. This is done with success in the case of smallpox and cholera, and this plan has eradicated hydrophobia; why should it not be carried out in the case of tuberculosis? Under present conditions men, women and children are going on unwittingly infecting one another by the thousand with tuberculosis in school, workshop and home, and we who know it take no public action and raise no clamant outcry against it. It is of more value to the community to isolate one pauper far advanced in tuberculosis than to send ten early cases to sanatoria. This disease must be stopped at its source as well as dealt with on its course. No disease has ever been eradicated from a community by discovering cures for it, and none ever will; many diseases have disappeared because their sources have been cut off.

Let us be scientific, let us search out the truth; having found it, let us act upon it, and let us conceal nothing that is true.

THE CULTIVATION OF WASTE LAND[1]

By A. D. HALL, M.A., F.R.S.

THE president of a Section of the British Association has two very distinct precedents before him for his address; he can either set about a general review of the whole subject to which his section is devoted or he can give an account of one of his own investigations which he judges to be of wider interest and application than usual. The special circumstances of this meeting in Australia have suggested to me another course. I have tried to find a topic which under one or other of its aspects may be equally interesting both to my colleagues from England and to my audience who are farming here in this great continent. My subject will be the winning of new land for agriculture, the bringing into cultivation of land that has hitherto been left to run to waste because it was regarded as unprofitable to farm. To some extent, of course, this may be regarded as the normal process by which new countries are settled; the bush is cleared and the plough follows, or under other conditions the rough native herbage gives way to pasture under the organized grazing of sheep or cattle. I wish, however, to deal exclusively with what are commonly termed the bad lands, inasmuch as in many parts of the world though recently settled, agriculture is being forced to attack these bad lands because the supply of natural farming land is running short. In a new country farming begins on the naturally fertile soils that only require a minimum of cultivation to yield profitable crops, and the newcomers wander further afield in order to find land which will in the light of their former experience be good. Before long the supply is exhausted, the second-class land is then taken up until the stage is reached of experimentation upon soils that require some special treatment or novel form of agriculture before they can be utilized at all. Perhaps North America affords the clearest illustration: its great agricultural development came with the opening up of the prairies of the Middle West, where the soil rich in the accumulated fertility of past cycles of vegetation was both easy to work and grateful for exploitation. But with the growth of population and the continued demand for land no soils of that class have been available for the last generation or so, and latterly we find the problem has been how to make use of the arid lands, either by irrigation or by dry-farming where the rainfall can still be made adequate for partial cropping, or, further, how to convert the soils that are absolutely poisoned by alkali salts into something

[1] Address of the president to the Agricultural Section of the British Association for the Advancement of Science, Australia, 1914.

capable of growing a crop. You yourselves will supply better than I can the Australian parallels, at any rate we in England read that the wheat-belt is now being extended into districts where the low rainfall had hitherto been thought to preclude any systematic cropping.

Now, the fact that the supply of naturally fertile land is not unlimited reacts in its turn upon the old countries. During the 'eighties and 'nineties of the last century the opening up of such vast wheat areas in America, Argentina, Australia, and the development of the overseas trade reduced prices in Europe to such an extent that in Great Britain, where the full extent of the competition was experienced, the extension of agriculture came to an end despite the continued increase of population. The area of land under cultivation has declined but little despite the growth of the towns, but the process of taking in the waste lands stopped and much of the land already farmed fell back from arable to cheaper pasture. But as soon as production in the newer countries failed to keep pace with the growth of population prices began to rise again, and we are now in the old world endeavoring to make productive the land that has hitherto been of little service except for sport and the roughest of grazing. Even the most densely populated European countries contain great areas of uncultivated land; within fifty miles of London blocks of a thousand acres of waste may be found, and Holland and Belgium, perhaps the most intensively cultivated of all western countries, possess immense districts that are little more than desert. Of the European countries, Germany has taken the lead in endeavoring to bring into use this undeveloped capital; her population is rising rapidly and her fiscal policy has caused her to feel severely the recent increase in the prices of foodstuffs, which she has determined to relieve as far as possible by extending the productivity of her own land. It has been estimated that Germany possesses something approaching to ten million acres of uncultivated land, and a government department has been created to reclaim and colonize this area.

Before dealing with the processes by which the rough places of the earth are to be made straight there is one general question that deserves consideration—Is it more feasible to increase the production of a given country by enlarging the area under cultivation or by improving the methods of the existing cultivators? There is without doubt plenty of room for the latter process even in the most highly farmed countries: in England the average yield of wheat is about 32 bushels per acre—a good farmer expects 40; the average yield of mangolds, a crop more dependent upon cultivation, is as low as 20 tons per acre when twice as much will not be out of the way with good farming. A large proportion of the moderate land in England is kept in the state of poor grass—even as grass its production might be doubled by suitable manuring and careful management, while under the plough its production of cattle-

food might easily be trebled or quadrupled. Why, then, trouble about adding to the area of indifferent land when so much of what has already been reclaimed, upon which the first capital outlay of clearing, fencing, roadmaking, etc., has been accomplished, is not doing its duty? We are at once confronted by the human factor in the problem. The existing educational agencies which will have to bring about better farming will only slowly become effective, and however imperfect they still may be in England, they are mainly so because of the lack of response upon the part of the farmers. The present occupiers of the land do obtain in many cases a very inadequate return from it, but they make some sort of a living and they hold it up against others who, though they want land, can not be guaranteed to use it any better. Improved farming means more enterprise, more knowledge, often more capital, and the man who can bring these to the business is far rarer than the man who, given a piece of land even of the poorest quality, will knock a living out of it by sheer hard work and doggedness. While, then, there should be no slackening in our efforts to improve the quality of the management of existing land, there is a case for also using every effort to increase the cultivable area; indeed, it is probable that for some time to come the second process will add most to both the agricultural production and the agricultural population.

Let us now consider what are the factors which determine the fertility of the land that is first brought into cultivation and remains the backbone of farming in the old settled countries. Foremost comes rainfall, and the distribution is almost as important as the amount. Winter rain is more valuable than summer, and though cereal-growing is none the worse and may even obtain better results with a rainless summer, stock-raising and the production of fodder crops are the better for a rainfall that is distributed fairly evenly throughout the year. Rainfall, again, must bear some relation to temperature; some of the best farming in the eastern counties of England is done on an average rainfall of 20 inches; there are great areas in South Africa with the same average rainfall that are little better than desert. In temperate regions we may say that the naturally fertile land requires a rainfall of from 20 to 50 inches per annum, not too much segregated into seasons and some at least falling in the winter.

If the rainfall is excessive or the drainage inadequate to carry it off, the formation of peat is induced, resulting in such uncultivated areas as the bogs of Ireland and the moors of eastern England, Holland and Germany.

Given suitable rainfall and temperature the texture of the soil becomes a factor of importance; if too coarse and sandy, so little of the rainfall is retained that we get all the effects of drought secondarily produced. In itself the open texture of a coarse sandy soil is favorable

to plant development; under irrigation, or where the situation is such as to result in permanent water a short distance below the surface, fine crops will be produced on sandy soils that would remain almost barren if they only depended upon the rainfall for their water. In western Europe large areas of heaths and waste land owe their character to the coarse and open texture of the soil. At the opposite extreme we find clays so heavy that their cultivation is unprofitable; such soils, however, will carry grass and are rarely left unoccupied. For example, in the southeast of England there are a few commons, *i. e.*, land which has never been regarded as worth enclosing and bringing into particular ownership, situated on heavy clay land; most of such land is pasture, often of the poorest, or, if at any elevation, has been covered with forest from time immemorial.

One last factor in the soil is of the utmost importance to fertility and that is the presence of lime—of calcium carbonate, to be more accurate—in quantities sufficient to maintain the soil in a neutral condition. Old as is the knowledge that lime is of value to the soil, we are only now beginning to realize, as investigation into the minute organisms of the soil proceeds, how fundamental is the presence of lime to fertility. A survey of the farming of England or western Europe will show that all the naturally rich soils are either definitely calcareous or contain sufficient calcium carbonate to maintain them in a neutral condition even after many centuries of cultivation. Examples are not lacking where the supply of calcium carbonate by human agency has been the factor in bringing and keeping land in cultivation. I have discussed one such case on the Rothamsted estate and several others have come under my notice. The amelioration of non-calcareous soils by treatment with chalk or marl from some adjacent source has been a traditional usage in England and the north of France: Pliny reports it as prevailing in Gaul and Britain in his day, and the farmer of to-day often owes the value of his land to his unknown predecessors who continuously chalked or marled the land. Upon the presence of carbonate of lime depends the type of biological reaction that will go on in the soil, the beneficial bacterial processes that prepare the food for plants only take place in a medium with a neutral reaction. The Rothamsted soils have provided two leading cases. I have shown that the accumulation of fertility in grass-land left to itself and neither grazed nor mown, so that virgin conditions were being re-established, was due to the action of the organism called Azotobacter, which fixes free nitrogen from the atmosphere, and was indirectly determined by the presence of calcium carbonate in the soil, without which the Azotobacter can not function. Examination of typical examples of black soils from all parts of the world, the prairies of North America, the steppes of Russia and the Argentine, New Zealand and Indian soils, showed in all of them the Azotobacter organism

and a working proportion of carbonate of lime. Now, as we know, all virgin soils are not rich, and only in a few parts of the world are to be found those wonderful black soils that are often several feet in depth and contain 10 to 20 per cent. of organic matter and 3 to 5 parts per thousand of nitrogen. These soils are all calcareous, they occur in regions of a moderate rainfall inducing grass-steppe or bush conditions, and the annual fall of vegetation provides the organic matter which the Azotobacter requires as a source of energy in order to fix nitrogen. Non-calcareous soils under similar climatic conditions do not accumulate nitrogen and become rich; in the absence of carbonate of lime the nitrogen-fixing organisms are not active, and the soil only receives from the annual fall of vegetation the nitrogen that was originally taken from it. There is but a cyclic movement of nitrogen from the soil to the plant and back again, whereas in the calcareous soils there is also continuous addition of fresh nitrogen derived from the atmosphere, in which process the carbonaceous part of the annual crop supplies the motive power.

The other leading case to be found at Rothamsted is that of certain grassplots which have artificially been brought into an acid condition by the continued application of sulphate of ammonia. In these soils nitrification is suspended, the nitrification organisms have even disappeared, though the herbage still obtains nitrogen because most plants are able to utilize ammoniacal nitrogen as well as nitrates. The interesting feature, however, is that the decaying grass on these acid soils passes into the form of peat, a layer of which is forming upon the surface of the soil, though nothing of the kind is found on adjacent plots where the use of lime or of alkaline manures has prevented the development of acidity. From this we may learn that the development of a surface layer of peat, independent of waterlogging (when another kind of peat forms even under alkaline conditions), is determined by the acidity of the soil, when certain of the bacterial processes of decay are replaced by changes due by micro-fungi which do not carry the breaking-down of organic matter to the destructive stage. This affords us a clue to the origin of many areas of upland peat in the British Isles, where the remains of ancient forest roots and stumps of trees are found on the true soil surface below the layer of peat, but where there is no waterlogging to bring about the death of the trees and the formation of peat. We may suppose that when the land-surface became fit for vegetation at the close of the glacial epoch it covered itself with a normal vegetation, chiefly dwarf forest, because of the rainfall and temperature. The soil, however, being without carbonate of lime, would in time become acid with the products of decay of the vegetable matter falling to the ground, and as soon as this acid condition was set up peat would begin to form from the grassy surface vegetation. The process would

continue until the acid conditions and the depth of the accumulating layer of peat would kill the trees, the stumps of which would remain sealed up below the peat. I am far from thinking that this explanation is complete, but at least we have facts in sight which could lead one to suppose that a non-calcareous soil originally neutral and carrying a normal vegetation can naturally become acid, alter the character of its vegetation and clothe itself with a layer of peat. The point of economic importance is that these peaty acid soils are of very little value as long as they are acid, though they take on a quite different aspect if they are limed and made neutral.

Of all the soil factors making for fertility I should put lime the first; upon its presence depend both the processes which produce available plant food in quantities adequate for crop-production at a high level and those which naturally regenerate and maintain the resources of the soil; it is, moreover, the factor which is most easily under the control of the agriculturist.

I need say little about those cases in which infertility is due to the presence in the soil of some substance which is actually injurious to plant-growth, because such substances are nearly always due to the physical environment of the soil, to too much or too little water. In water-logged situations we may find in the soil peaty acids, iron salts, sulphides, etc., inhibiting the growth of plants; in arid regions the soil may still be charged with an excess of soluble compounds of the alkalis and alkaline earths, resulting from the decomposition of the rocks that have been broken down to form the soil, but which through the inadequate rainfall have never been washed out. The establishment of normal conditions of growth, irrigation in the one case, drainage in the other, will speedily result in the removal of the deleterious substances. Practically, only bodies that are soluble can get into a plant to injure it, hence such bodies can be removed from the soil by water, provided that the water can find its way through the soil and escape.

Let us now consider the various methods by which land suffering from one or other of the disabilities we have just discussed is nowadays being brought into cultivation. The most important, if we consider the area affected, is the extension of cropping into regions of deficient rainfall by means of what has been termed dry-farming. As far as its immediate methods go, dry-farming consists in nothing more than the application of the principles of husbandry worked out by English farmers in the east and southeast of England, principles first expounded by Jethro Tull, though a complete explanation was not then possible, even if it is now. In the first place, the tilth must be made both deep and fine, thus whatever rain falls will be absorbed and the conditions favoring a deep and full root range will have been established. Next, the soil below the surface, though finely worked, must be compact, be-

cause only thus can the water present travel to the roots of the plant. Lastly, a loose layer must be maintained on the surface, which, though dry itself, acts as a screen and a barrier to prevent loss of water from the effective soil below by any other channel than that of the plant. Granted these methods of cultivation, the new feature about "dry-farming," which has been introduced by settlers in the arid districts of Australia and North America, is the use of a year of bare fallow in which to accumulate a supply of water for the next year's or two years' crop. This raises the fundamental question of how much water is necessary for the growth of an ordinary crop. The first investigation that Lawes and Gilbert carried out at Rothamsted dealt with this very point; they grew the usual field crops in pots, protected the surface of the soil from evaporation so that all the loss of water proceeded through the plant, weighed the water that was supplied from time to time, and finally weighed the produce, expressing their results as a ratio between the dry matter produced and the water transpired by the plant. These experiments have been repeated under different climatic conditions by Hellriegel in Heidelberg, by Wollny in Vienna, by King and others in America. Now the two processes in the plant, carbon assimilation and transpiration, are not causally connected, though as both are carried out in the leaf and have some factors in common they are found to show some constancy in their relative magnitudes. Lawes and Gilbert obtained a ratio of about 300 lbs. of water transpired for each pound of dry matter harvested, but the other investigators under more arid conditions found much higher figures, up to 500 and even 700 to 1. Now, a crop yielding 20 bushels of wheat per acre will contain about a ton of dry matter per acre, so that, taking the high ratio of 500 to 1, no more than 500 tons of water per acre or 5 inches of rain will have been consumed in the production of this crop. It is, of course, impossible to ensure that all the rain falling within a year shall be saved for the crop, much must evaporate before it reaches the subsoil where it can be stored, and only when the crop is in full possession of the land can we expect that all the water leaving the soil shall go through the crop. What proportion the waste bears to that which is utilized will depend not only on the degree of cultivation but upon the season at which the fall occurs; summer showers, for example, that do not penetrate more than a few inches below the surface will be dissipated without any useful effect. When the climatic conditions result in precipitation during the winter, the water will be in the main available for crop-production; and it has been found by experience that cereals can be profitably grown with as small a rainfall as 12 inches. The necessary cultural operations consist in producing such a rough surface as will ensure the water getting into the subsoil, hence autumn ploughing is desirable. Where the precipitation is largely in the form of snow, a broken surface also helps both

to absorb the thawing snow and to prevent it being swept into the gullies and hollow places by the wind. On some of the Russian steppes it has become customary to leave a long stubble in order to entangle as much snow as possible, but probably a rough ploughing before the snowfall would be even more effective. When the rainfall drops to the region of 12 to 16 inches and occurs during the summer months, then dry-farming methods and the summer fallow become of the first importance. The deep cultivation ensures that the water gets quickly down to the subsoil away from danger of evaporation, and the immediate renewal of a loose surface tilth is essential in order to conserve what has thus been gained.

In connection with this dry-farming there are several matters that still require investigation before we can decide what is the minimum rainfall on which cultivation can be profitable. In the first place, we are only imperfectly informed as to the relation between rainfall and evaporation. At Rothamsted there are three drain-gauges side by side, the soil layers being 20, 40 and 60 inches deep, respectively. The surface is kept rough and free from growth, though hardly in the condition of looseness that could be described as a soil mulch. Yet the evaporation, even under a moist English atmosphere, amounts to one half of the annual rainfall, and the significant thing is that the evaporation is approximately the same from all of the gauges and is independent of the depth of subsoil within which water is stored. Evaporation then would seem to be determined by surface alone, but we are without systematic experiments to show how variations in the surface induced by cultivation will alter the rate of evaporation. A knowledge of the evaporation factor would then inform us of what proportion of the rainfall reaches the subsoil; we then want to know to what extent it can be recovered and how far it may sink beyond the reach of the crop. It is commonly supposed that the subsoil below the actual range of the roots of the crop may still return water by capillarity to the higher levels that are being depleted, the deeper subsoil thus acting as a kind of regulating reservoir absorbing rain in times of excess and returning it when the need arises. But some work of Leather's in India and Alway's on the great plains of North America throw doubt on this view, and would suggest that only the layer traversed by roots, say, down to a depth of 6 feet, can supply water to the crop; the water movements from the deeper layers due to capillarity being too slow to be of much effect in the maintenance of the plant. The evidence on either side is far from being conclusive and more experiment is very desirable.

It would also be valuable to know how far evaporation from the bare soil can be checked by suitable screens or hedges that will break the sweep of the wind across the land. In England hedges have always been looked at from the point of view of shelter from stock; we find them most developed in the grazing districts of the west, while bare

open fields prevail in the east and south. Yet the enormous value of a wind-screen to vegetation can be readily observed, and the market-gardeners both in England and the still dryer districts of the south of France make great use of them. Lastly, we must have more knowledge about the relation between transpiration-water and growth: we do not know if the high ratios we have spoken of hold for all plants. Xerophytic plants are supposed to be possessed of protective devices to reduce loss of water: Are they merely effective in preserving the plant from destruction during the fierce insolation and drying it receives? and do they enable a plant to make more growth on a given amount of water? Wheat, for example, puts on its glaucous waxy bloom under dry conditions: Is this really accompanied by a lower rate of transpiration per unit surface of leaf? and is it more than defensive, connoting a better utilization of the water the plant evaporates?

The cultivation of these soils with a minimum rainfall necessitates varieties of plants making a large ratio of dry matter to water transpired and also with a high ratio between the useful and non-useful parts of the plant. Mr. Beaven has shown that the difference in the yields of various barleys under similar conditions in England is due to differences in their migration factors: the same amount of dry matter is produced by all, but some will convert 50 per cent. and others only 45 per cent. into grain. This migration ratio, as may be seen by the relation between corn and straw on the plots at Rothamsted, is greatly affected by season; nevertheless Mr. Beaven's work indicates that under parallel conditions it is a congenital characteristic of the variety and therefore one that can be raised by the efforts of the plant-breeder. The needs of dry-land-farming call for special attention on the part of the breeder to these two ratios of transpiration and migration.

Closely linked up with the problems of dry-land-farming are those which arise in arid climates from the use of irrigation-water on land which is either impregnated with alkaline salts to begin with or develops such a condition after irrigation has been practised for some time. The history of irrigation-farming is full of disappointments due to the rise of salts from the subsoil and the subsequent sterility of the land, but the conditions are fully understood and there is no longer any excuse for the disasters which have overtaken the pioneers of irrigation in almost every country. Sterility may arise from two causes—overmuch water which brings the water-table so close to the surface that the plants' roots may be asphyxiated, or the accumulation by evaporation of the soluble salts in the surface layer until plants refuse to grow. The annual cutting off of the cotton crop in Egypt as the water-table rises with the advance of the Nile flood affords a good example of asphyxiation, but in the neighborhood of irrigation canals we also find many examples of sterility due both to the high water-table and an accom-

panying rise of salts. The governing principle is that drainage must accompany irrigation. Even if free from salts at the outset the land must accumulate them by the mere evaporation of natural waters, and they will rise to the surface where they exert their worst effect upon vegetation, unless from time to time there is actual washing through the soil and removal of the water charged with salt. Without drainage the greater the quantity of water used the greater the eventual damage to the soil, for thereby the subsoil water-table carrying the salts is lifted nearer to the surface. With a properly designed irrigation system the danger of salting ought not to occur; there are, however, many tracts of land where the supply of water is too limited to justify an expensive scheme of irrigation channels with corresponding drainage ditches at a lower level. Take the case of a single farmer with some water from an artesian well at his disposal, with perhaps little rainfall, with land subject to alkali, and no considerable natural fall for drainage. If he merely grades the land and waters it, sterility rapidly sets in; the only possibility appears to be to take a comparatively limited area and to cut out drainage ditches or tile drains 4 or 5 feet below the surface, even if they have to be led into a merely local hollow that can be abandoned to salt. The bed thus established must then be watered at any cost until there is a flow in the drains, after which the surface is immediately cultivated and the crop sown. There should be no further application of water until the crop covers the land, the use of water must be kept to a minimum, and by the ordinary methods of dry cultivation evaporation must be allowed only through the crop, not merely to save water but to prevent any rise of salt. With a loose surface and wind-breaks to minimize evaporation it has thus proved possible to grow valuable crops even on dangerously alkaline land. Superphosphate and sulphate of ammonia have proved to be useful fertilizers under these conditions; both tend to prevent the reaction of the soil becoming alkaline, and the calcium salts of the superphosphate minimize the injurious effects of the sodium salts that naturally accumulate in the land. On the other hand, nitrate of soda is a dangerous fertilizer. Attempts have been made to reduce the salts in the land by the growth of certain crops which take up a large proportion of mineral matter, but I have not been able to ascertain that much good can be thus effected. Sugar-beet and mangolds do appreciably reduce the salt content, but are hardly valuable enough to pay for such special cultivation and the limited irrigation-water; the best thing appears to be to grow salt-bush on the non-irrigated margin of such areas, if only to prevent the efflorescent salts from blowing on to the cultivated portion.

Let us now turn to the problem of land reclamation as it occurs in northwestern Europe. There are two main types of land that have hitherto been left waste, the peaty and the sandy areas. Of the peaty

areas we can distinguish again between the low-lying moors bordering the lower courses of the great rivers; for example, in England near the mouth of the Trent, and the upland peat-bogs of which Ireland furnishes so many examples. They have these features in common—an excess of water, a deficiency of mineral salts, and, particularly in the upland bogs, a strongly acid reaction; but they possess great potential wealth in their richness in nitrogenous organic matter. It is in Germany and Holland that the methods of bringing into cultivation these moors have been most completely worked out; in Germany, for example, it is estimated that there are about five million acres of moorland of which about 10 per cent. are now under cultivation. The reclamation process must begin by drainage, which may be carried out by open ditches, but is most satisfactorily effected by pipes, despite the greater cost. The water-table must be kept some 3 feet below the surface. In districts which afford a market for peat, as, for example, on the Teufelsmoor near Bremen, the reclamation often begins by cutting out the peat, the lower layer of firm peat being won, dried, and sold for fuel. The upper spongy peat can be used for litter, but some part at least must be thrown back. Where the burning peat is thus extracted the excavation is in places pushed further until the underlying sand is reached, and enough of this is dug to spread over the reclaimed area to a depth of 4 or 5 inches and mixed by cultivation with the spongy peat. Even when the peat is not removed, pits are often made in order to sand the land, so great an improvement does it effect in the character of the crops. However, sanding is not possible everywhere, and there are great areas under cultivation where the reclamation begins with drainage, followed by the cultivation of the immediate surface without either sanding or the removal of the burning peat, which indeed are impossible over large areas, but are carried out by the owners of small farms little by little. Special tools are required: certain forms of disc-ploughs and harrows give the best results; heavy tools for large scale cultivation by steam or electricity are furnished with broad roller-like wheels; even the horses must wear broad wooden shoes.

The next stage is the manuring, and it has only been the development of the artificial fertilizer industry during the last half-century that has rendered the cultivation of this type of land possible. On the alluvial moors where the ground water has always been alkaline, the peat is rich in calcium and no treatment with lime and marl is necessary (the English fens afford an example of this type of soil), but on the true peat-bogs (Hochmoor of Germany) the manuring must begin with a good dressing of burnt lime, or, better, of marl or ground chalk. For meadows and pastures two tons per acre of lime, or twice as much of carbonate of lime, should be applied; the amounts may be halved for arable land. This must be followed by about 5 to 8 cwt. per acre

of basic slag and an equal amount of kainit, which applications should be renewed in the second year, but then diminished in accord with the cropping. However, some phosphoric acid and potash salts must be continuously supplied, with occasional dressings of lime or chalk on the acid peaty areas. These latter also require in their earlier years nitrogenous manures, for the peat is slow to yield up the nitrogen it contains. The fertilizers should be nitrate of soda or lime, never sulphate of ammonia. The whole success of the reclamation depends on the use of these manures, as the peat in a state of nature is almost devoid of both phosphoric acid and potash; on the acid peats, again, normal growth is only possible after a neutral reaction has been attained by the use of lime or marl. With this manuring it is found to be easy to establish a good meadow herbage in a very short space of time; it is not even necessary to get rid of the surface vegetation of *Erica* and other heath and bog plants. The manure is put on and the surface is worked continuously with disc-harrows and rollers, but never deeply; a seed-mixture containing chiefly red, white and Alsike clovers, *Lotus uliginosus,* rye-grass, timothy and cocksfoot, is sown in the spring and soon succeeds in choking the native vegetation.

It is impossible to say what is the cost of the reclamation of moorland in this fashion; the big expense is the drainage and the construction of roads, both of which are entirely determined by local conditions. But of the value of the process when accomplished there can be no doubt. I have seen a case quoted from the *Ostfriesische Zeitung,* where a piece of moor bought for £75 was reclaimed and sold for £900; and, best test of all, one may see in places like the Teufelsmoor near Bremen, families living in comfort on thirty to forty acres of what was once merely wild moor with no productive value.

Of even greater interest in England is the reclamation of heathland, which has of late years been proceeding apace in Germany. In this category we may include all land which owes its infertility to the coarse grade and low water-retaining power of the particles of which the soil is composed, the soil being at the same time as a rule devoid of carbonate of lime, and covered in consequence with heather and similar calcifuge plants. In England there exist extensive tracts of uncultivated land of this character in close proximity to the considerable populations, but the process of reclaiming such land for agriculture seems to have come to an abrupt conclusion somewhere about 1850, when the developing industries of the country began to offer so much greater returns for capital than agriculture. That land of the kind can be cultivated with success is evident from the mere fact that everywhere prosperous farms may be seen bordering the wastes, possessing soils that are essentially identical with those of the wastes. These were brought under cultivation when labor was cheaper, often without calculation of the cost because

the work was done piecemeal at times when the men would otherwise have been idle. Were any strict account to be framed, the reclamation probably did not pay its way for many years, and it has only become possible again because of modern advances in science and machinery. As examples of the type of land, I may instance the Bagshot Sands on which, in north Surrey, in Berkshire and Hampshire, and again in its southern development in the New Forest, lie so many thousands of acres of uncultivated heath. No systematic reclamation has taken place, but everywhere farms have been carved out on this formation often by the industry of squatters, and within reach of London the vast supplies of town manure which used to be available have converted some of it into fertile land. The crystallization of common rights into charters for public playgrounds, its growing appreciation for residential purposes, will now always stand in the way of the utilization of most of the Bagshot Sands for agriculture, but further afield there are many areas of similar character. The Lower Greensand is perhaps equally discounted by its residential value, but on the Tertiaries of Dorset, the Crag and Glacial Sands of Suffolk and Norfolk—the brak, the Bunter Beds of the Midlands, lie many expanses of waste that are convertible into farming land, just as Lincoln Heath and much of the beautifully farmed land of Cheshire have been gained for agriculture within the past century. Equally possible is an attack upon the sandy areas, warrens or links, behind the sand-dunes on many parts of the English and especially the Welsh coasts; not all of them are wanted for golf, and many can be fitted for market-gardening. Of old the only way of dealing with such land was merely to clear it, burn the rubbish, and start upon the ordinary routine of cultivation, but for a long time on such a system the crops will hardly pay their way from year to year, and the permanent deficiencies of the soil in lime and mineral salts remain unrepaired. In Cheshire the enormous value of marl and bones in such a connection was early recognized; it has been the later discovery of the potash salts that renders reclamation a commercial proposition to-day. The method that is now followed is to begin by clearing the land of shrubs, burning off the roughest of the vegetation, and turning over a shallow layer in the summer, leaving the heathery sod to the killing and disintegrating action of sun and frost until the following spring. The manure is then put on—lime or ground chalk or marl as before, basic slag and kainit, and the sod is worked down to a rough seed-bed on which lupins are sown, to be ploughed in when they reach their flowering stage. The growth of the lupins makes the land, they supply humus to bind the sand together and retain moisture, they draw nitrogen from the atmosphere and with the phosphoric acid and potash form a complete manure for succeeding crops. Sometimes a second crop of lupins is ploughed in, but usually the land is put immediately to an

ordinary rotation of rye, oats, potatoes and clover. When the heath-land is divided among small tenants in an unreclaimed state, cropping often begins without the lupins, the necessary nitrogen being imported by nitrate of soda, but for years the land shows inferior results. Only the tenant can rarely afford to lose the year the lupin crop involves, and so great is the demand for land in Germany that the State finds it preferable to let the tenant reclaim than to reclaim for him, and charge him as rent the cost of the more thorough process. And now as to the finance of the operation: the reclaiming down to the ploughing in of the lupin crop costs from £5 to £6 an acre, the bare heath costs from £5 to £7 an acre, the reclaimed land after a few years' cultivation would sell at £20 to £30 an acre. Meantime the State has probably made a free grant for drainage, looking to get some interest back in increased taxation; the local authority has also made roads for which the increased rating due to a new agricultural community must be the only return. It is a long-sighted policy which will only find its full justification after many years when the loans have all been paid off and the State has gained a well-established addition to its agricultural land and its productive population. In comparing English with German conditions there are certain differences to be taken into account—in the first place the work of reclamation will be dearer in England because of the higher price of labor, then the land will not be so valuable when won because the higher scale of prices for agricultural products enhances the price of land in Germany. Next, I doubt, in view of the great industrial demand for men in England, if we have the men available who will bring to the land the skill and power of drudgery that I saw being put into these German holdings of thirty to forty acres in their earlier years of low productivity. Moreover, in Germany these heaths are generally bordered by forests, in which the small holder gets occupation for part of the year while his wife and children keep the farm going. For this, if for no other reason, afforestation and land reclamation and settlement should go on together. But, despite these drawbacks, I am still of opinion that the reclamation of such heath-lands is a sound commercial venture in England, either for a landowner who is thinking of a future rather than of a present return on his capital, or for the state or other public body, wherever the waste land can be acquired for less than £5 an acre. The capitalized value of its present rental rarely approaches that figure, but the barrenest heath is apt to develop the potentialities of a gold-mine when purchase by the state comes in question. The map of England is so written over in detail with boundaries and rights and prescriptions that the path of the would-be reclaimer, who must work on a large scale if he is to work cheaply, can only be slow and devious. There are other possibilities of winning agricultural land even in England, from the slob land and estuaries, from the clays now-

adays too heavy for cultivation; but the problems they present are rather those of engineering than of agricultural science. What I should like in conclusion once more to emphasize is, that the reclamation of heath and peat-land of which I have been speaking—reclamation that in the past could only be imperfectly effected at a great and possibly unremunerative expense of human labor—has now become feasible through the applications of science—the knowledge of the functions of fertilizers, the industrial developments which have given us basic slag and potash salts, the knowledge of the fertility that can be gained by the growth of leguminous plants. From beginning to end the process of reclamation of moor and heath, as we see in progress in northwestern Europe, is stamped as the product of science and investigation.

HOME RULE THE HOPE OF MUNICIPAL DEMOCRACY

By OSWALD RYAN
ANDERSON, IND.

IF the final test of democracy in America is to come in the cities, as Jefferson phophesied in his "Notes on Virginia," it would seem that the test should at least be a fair one. Yet the municipal machinery of the average American state permits anything but a fair trial of the democratic principle. For, every student of contemporaneous municipal conditions knows that, barring those progressive communities that have adopted some form of commission government, city government is still cursed with the curse of divided responsibility, is still in the hands of men who can not apply the rules of municipal efficiency because they are bound by the rules of the partisan game. In these cities men are still elected to office by national party organizations without regard to questions of local policy, and men are still appointed to municipal positions because of what they have done for their party rather than because of anything they can do for their city.

Deplorable as it is, the worst thing about this system of city government is that it is not the free choice of the cities that are the victims of it, but an imposition by an outside authority—the state legislature. For, under the ordinary state constitution, the city is not, in theory of law, a self-governing community, but a subject province exercising its limited powers by sufferance of the state legislature, and having this or that form of government as may be superimposed by the outside sovereign. The municipality does not even possess the right to its own existence; it exists only by grace of the state legislature, which, if it pleased to do so, could withdraw its lease of life at will.

Thus the city takes its right to existence, its form of government and its governmental powers from the state, and what the state can give the state can take away. The legal validity of any act by the city, such as the issuing of bonds, the contracting for a municipal waterworks or the granting of a municipal franchise, is not determined by the expressed desire of its citizens, but by the voice of the legislature as set out in some statute. The real seat of municipal authority, therefore, is not in the citizens, but in the state legislature; the city lives and moves and has its being in the will of the state.

Under this system of constitutional law the cities exercise those powers that are enumerated in the state legislature grants, and only those powers. If the city wants to exercise a specific power of local

government for the satisfaction of a local need, it must search the statutes for permission, and if the statutes are silent on the point, it must appeal to the state legislature for the requisite power. Thus, if a city in my own state of Indiana, for example, wishes to furnish ice to its citizens in the heat of summer, establish a pension fund for its teachers or institute a civil service test for its employees, it must make its humiliating appeal to the legislative Cæsar at Indianapolis; for these powers are not nominated in the bond. No wonder an exasperated Indiana city official was once led to remark that "the only creatures without rights under our law are outlaws, wild beasts and municipalities." Yet, that local communities shall have the fullest right of local self-government is a maxim of American institutions.

Not only must the city in the exercise of its enumerated powers keep strictly within the limits set by the state legislature, it must follow only such administrative methods as the legislature has prescribed. Even in the determination of the fundamental framework of their government the citizens have no legal voice. A certain city may desire the commission plan or the city manager plan; but, of its own action, it can not get what it wants. It must take what it gets from the state house, and in the large number of states of which I am writing it gets an antiquated form of city organization that renders increasingly difficult the municipal problem. And not only the general framework, but the minutest detail of the administrative machinery, is often prescribed by legislative act.

Generally the legislature groups the cities in classes according to their population, and then imposes a detailed plan of administrative organization and powers upon each class. This frequently means that a particular city is saddled with an administrative machinery ill-fitted to its local conditions, or with administrative methods ill-adapted to its local needs. Any one who is familiar with municipal conditions knows that even cities of the same general size often reveal the greatest diversity of conditions and needs, and that what is good for one city is often bad for another. Moreover, to imprison the city in the strait-jacket of uniform legislation checks its inventiveness, for it deprives it of the opportunity of wholesome experiment with municipal methods. It impairs its individuality, for it takes from it the chance to shape its own life and development. It lessens its sense of responsibility, for it relieves it of the responsibility of working out its own civic salvation. Common sense joins with the principle of local self-government in the demand that local institutions be permitted to conform to local conditions.

To meet the needs of modern social and economic development the American city without right of self-government is compelled by the state constitution to appeal at every turn to the legislature for relief; but that constitution never guarantees that the city's prayer

shall be answered, or that it shall even be considered on its merits. Who can deny that politics-ridden legislatures have often refused to hear the appeal of the city for no other than a purely partisan reason? Who will deny that, just as burdensome laws have often been imposed upon the city for partisan purpose, so needed legislation has often been denied the city for partisan advantage? The legislative history of every state abounds with testimony to show that legislative dominion over municipal affairs has been as discreditable to the state as it has been unhealthy for the city.

Not only does the partisan character of the state legislature disqualify it for the function of guiding the administrative development of the cities, but the individual legislators have neither the time nor the knowledge of local conditions nor the proper sense of responsibility to the urban constituency necessary to a constructive treatment of the municipal problem. Members of the legislature are largely from the rural districts and can not in reason be expected to understand the perplexing problems of municipal government. Yet, to these men, untrained in the intricacies of municipal administration, unfamiliar with actual city conditions and busy with many problems of state policy, has been intrusted the tremendous task of controlling the city's administrative development. It is no reflection upon the ability or intelligence of our legislators to say that they are ill-fitted for this task of absentee law-making.

Aside from making impossible an effective solution of the municipal problem, this legislative dominion over the city impairs the efficiency of the legislative members in the other work which they have to do. In Indiana, for example, the legislative desks for years have groaned under the burden of bills having for their object to grant to cities relief from the restrictive provisions of our state constitution and laws. During the past few sessions a perfect flood of measures dealing with matters of a purely local nature engrossed legislative time and energy that should have been put upon important matters of general state policy. We have rid ourselves by a federal constitutional change of one great obstacle to legislative efficiency—the indirect election of United States Senators; it now remains to rid ourselves by state constitutional change of another great obstacle—the legislative regulation of municipal affairs. This can be done by writing into the state constitution provisions for municipal home rule. Already several states have adopted this needed reform.

What does "municipal home rule" mean? It means, in the first place, a reversal of the existing legal presumption against the powers of the city. Instead of possessing only such powers as are granted to it by the state legislature, the city, under the "home rule" system, is invested by the constitution with all powers of local government con-

sistent with the general laws of the state. In this way is created an unmolested sphere of local self-government in which the city may exercise all powers necessary to its own complete development, without the necessity of recourse to any outside authority and without the danger of interference from any outside authority. Municipal home rule means further that the city may determine its own form of government, or as Herbert Bigelow put it, "may cut out its own municipal suit of clothes." Thus the city decides for itself, by means of a charter convention and ratification election, whether it will have the commission plan, the city manager plan, the mayor-and-council system or any other form of municipal organization.

And why not? Who know better than the citizens of Indianapolis the needs of Indianapolis and the administrative agencies that are adapted to those needs? Who can determine better than the citizens of Lexington, Kentucky, the activities of public welfare in which the government of Lexington should engage? If Terre Haute, Indiana, wants a non-partisan form of city government why should not Terre Haute have that form? There appears to be no reason for excepting cities from the operation of the principle of self-government that does not apply with equal force against the principle of democracy itself.

Ours are the only English-speaking cities in the world that are denied the right of self-government. One can not imagine, for example, legislative intermeddling in the affairs of an English city, which is permitted by Parliament to develop in its own way and according to its own ideas of administrative organization. English cities since 1832 have been among the best governed in the world and American cities have been among the worst governed. What accounts for this difference between the municipal experience of two English-speaking peoples? The main reason is that English cities are self-governed and American cities are state-governed. The citizens of Birmingham govern Birmingham; the legislature of Indiana governs Indianapolis.

Home rule for cities means municipal self-government, but it does not mean municipal independence in the sense that there are created independent sovereignties within the state. It does not mean that the state government loses its control over matters that concern the general state welfare. Thus home rule does not require that the state surrender entirely its control over elections in which state officers are chosen, for the people of the commonwealth as a whole are vitally interested in maintaining the purity of the ballot and in the prevention of corrupt and fradulent practices. It does not mean that the state resigns its power to pass laws relative to the health, safety and general welfare of its citizens. The state at large is vitally interested in the prevention of crime and disease and in the education of the people, and, although it may leave the city free to provide its own administrative machinery

and allow a wide diversity in methods, it must maintain a general supervisory control over these subjects. In other words, the city government is not only an organ for the satisfaction of local needs, but an agent of the state for the performance of state functions. The doctrine of home rule recognizes this. It renders to the city the things that are the city's, and to the state the things that are the state's.

So defined—and it has been so defined by the states which have written it into their fundamental law—the principle of municipal home rule may be regarded as the first step in the direction of a responsible and efficient city government. Wherever it has been put into the constitution of a state a larger municipal vision has been created and a new brand of municipal administration has appeared. Thus it is a significant fact that many of the most advanced forms of city government have grown up in the cities which have enjoyed constitutional home rule. Given the right to determine its own destiny, the city becomes the hope, instead of the despair, of democracy. And the test which democracy receives will be a fair one.

THE POLITICAL MIND OF FOREIGN-BORN AMERICANS

By ABRAM LIPSKY, Ph.D.
NEW YORK CITY

AN election is a psychological experiment on a large scale. The trouble with most elections, however, as psychological tests, is that the questions submitted are vague, complex and variously understood. If one could put a simple and unequivocal question such as "Are you in favor of capital punishment?" or, "Do you prefer co-operative to family housekeeping?" the answers might be of great informative value as to the mind of the population. If such questions could be submitted, it would then be interesting in analyzing the returns to look for the influence of economic, social and racial factors.

The City of New York, as it happens, is an excellent laboratory for studying the responses of several foreign nationalities. There are, according to the Thirteenth Federal Census, 340,765 Italians in New York who were born in Italy, 484,189 foreign-born Russians, 278,114 foreign-born Germans, 252,662 Irish, born in Ireland. These nationalities are not evenly distributed over the area of the city. Here and there exist communities as large as good-sized cities composed almost entirely of people of one nationality, and these communities constitute distinct political units, to the extent that a ward or an assembly district is a distinct political unit. Thus there were in the eighth assembly district in 1910, 51,438 foreign-born Russians; 83.8 per cent. of the males of voting age were foreign-born and naturalized; only 2.5 per cent. were native born, of native parents. In the third assembly district there were 33,531 foreign-born Italians; in the sixteenth there were 9,144 Irish from Ireland; in the third district of Queens County there were 15,548 Germans born in Germany. We are thus enabled to pick out districts in which one or other nationality largely predominates and from the election returns can determine how the district voted upon every candidate or proposition submitted.

Candidates are but rarely propositions. Only when they are does an election take on the character of an experiment in social psychology. Now, the election of November, 1913, was one of the rare sort. The issues were clear, simple, unequivocal, understood very generally in the same sense. The propositions for which the candidates stood might have been formulated as follows: (1) Are you in favor of government by an organization such as Tammany? (2) Are you in favor of Socialism? (3) Do you read the

Hearst newspapers regularly? These questions have not in recent years been put so clearly—not in 1910 when the campaign for the governorship was complicated by the intervention of Roosevelt in favor of Stimson, not in 1911 when only minor officials were elected, not in 1912 when the personal element again was paramount.

In view of the prevalent solicitude concerning the effect of racial conglomeration upon American national life, it is of great practical importance to ascertain as definitely as possible what the behavior of different races constituting the American population is in response to specific appeals. Does nationality play any part in determining the point of view of our foreign communities in political matters? Will American problems be dealt with in the same way by one of the foreign districts as by a community of native Americans born of native parents?

From the Thirteenth Census, which gives the number of specified nationalities in each assembly district, and also the number of naturalized voters, one can deduce approximately the percentage of voters belonging to each nationality in every district.

We shall first consider the answers of the chief constituent nationalities of New York to the question: "Are you in favor of government by political organizations of the Tammany kind?"

We present to begin with a table giving the ten districts in which the voters of native parentage were found in the greatest numbers. The first column gives the borough and district, the second, the per cent. of all the voters constituted by the Americans of native parentage, the third, the per cent. of the whole vote in each district given to the Tammany candidate for mayor. In the fourth, the vote for Dix, Tammany candidate in 1910, is added:

Assembly District	Native of Native parents	1913, McCall	1910, Dix
M 15	45.3	33.7	58.1
M 19	40.0	33.2	52.3
M 25	44.1	35.3	48.4
M 27	51.5	37.6	55.8
Q 4	41.3	31.1	46.2
B 17	45.6	24.7	43.6
B 11	38.0	34.9	50.5
B 18	39.0	28.3	46.3
B 5	38.1	25.3	44.1
B 10	38.6	36.6	53.3

These districts of mainly American voters answered "nay" to Tammany, throwing in every case over sixty per cent. of their votes against it. In 1910 Dix received a little over 50 per cent. in half of these districts, but as has been said, Tammany was not then the sole issue.

There is no difficulty in finding a dozen districts in which the Russians alone far exceed every other nationality in number. As is well

known, the Russians are nearly all Jews, and so are the Austrians who in large numbers inhabit some of these districts. The next table is similar to the first except that Russians and Austrians are substituted for native Americans.

Assembly District	Russians	Austrians	Both	1913, McCall	1910, Dix
M 8	54.4	14.2	68.6	40.2	52.3
M 6	30.4	30.8	61.2	22.8	40.
M 4	35.6	25.2	60.2	51.1	61.7
M 26	34.6	6.7	41.3	30.0	41.0
M 2	35.6	1.4	37.0	57.6	67.5
M 10	22.3	12.5	36.8	29.3	52.2
M 24	20.6	3.9	23.9	49.7	56.8
M 31	12.9	4.9	17.8	24.1	44.7
B 21	31.2	5.9	37.1	27.1	48.6
B 23	33.3	3.9	37.2	25.7	40.9
B 14	16.1	5.9	22.0	46.6	61.5
B 22	13.0	3.0	16.0	24.3	38.5

In only two of these districts did McCall receive more than 50 per cent. In two thirds of the districts he received much less than the average for the entire city which was 38 per cent. The Russians, too, emphatically said "nay" to Tammany in 1913.

Let us now put the same question to the Italians. There are four assembly districts in which the Italians far outnumber every other nationality; there are two others in which they exist in great numbers, although by the side of one or other nationality that rivals or exceeds them numerically. The following table gives the figures as in the preceding tables:

Assembly District	Italians	1913, McCall	1910, Dix
M 3	30.3	67.6	77.7
M 1	25.2	59.6	67.8
M 28	26.8	42.6	55.8
B 3	23.2	63.7	73.1
B 2	13.4	60.0	67.7
M 2	18.5	57.6	67.4

In three of these districts the Tammany candidate received over 60 per cent. of the votes; in two over 50 per cent. and in one over 40 per cent. It is evident that the Italian districts said "yea" to Tammany as emphatically as the districts of the Russians and native Americans said "nay."

Statistics are hardly necessary to teach the student of politics how Irishmen are inclined to answer the question we have been considering. Our figures support the view that they are for the Tammany organization. We take for study the five districts in which the foreign-born Irish are most numerous. It should be remembered, however, that our figures underestimate the voting strength of the Irish in these districts;

first, because the percentage of naturalization of the Irish is much greater than that of Italians or Russians on account of their being older immigrants and also more at home in the peculiar political milieu of New York; second, the native Irish of foreign parents usually outnumber the foreign born, whereas the opposite is true of the relation between native-born and foreign-born Russians and Italians. Besides, the Irish are widely scattered and massed in only a few districts. However, these are the districts we have, at present, in view, as giving a strong clue to what occurs less perceptibly where the concentration is less dense. The table follows:

Assembly District	Irish	1913, McCall	1910, Dix
M 13	16.4	61.0	58.1
M 16	14.0	51.7	61.4
M 11	12.2	55.6	60.5
M 14	12.4	54.7	61.2
M 5	11.2	64.4	67.6

We have only five districts in which the naturalized Irishmen constitute clearly over 10 per cent. of the voting population. In every one the Tammany candidate received over 50 per cent. of the district's vote. Although not an exact measure of the strength of the Irish predilection for the organization, it is a clear indication of the tendency sufficiently demonstrated in other ways.

The Germans, like the Irish, are more diffused than the Russians and Italians. We find them constituting more than 10 per cent. of the voters in six districts. In two of these they far outnumber every other nationality—the third of Queens and second of Manhattan. In these they formed considerably more than twenty-one per cent. of the voters.

Assembly District	Germans	1913, McCall	1910, Dix
Q 3	21.4	31.1	49.8
B 20	20.2	26.8	41.8
B 19	13.6	31.9	48.3
B 33	11.2	34.6	49.4
Q 1	11.1	41.4	55.2
M 22	21.2	38.4	50.5

Every one of these districts decisively rejected Tammany.

Summarizing the answers given to the first question put to the voters, which was "Are you for or against Tammany" we are able to say that a decided "no" was given by native Americans of native parents and by the Russians and Germans; a decided "yes" was given by the Italians and Irish.

Two other questions came sharply to the fore in 1913. One was radicalism in the form of socialism; the other was Hearstian radicalism.

How do the foreigners stand towards these movements? There is a widespread though vague impression that socialism is a phenomenon of foreign growth. We can be more specific.

The city at large gave the socialist candidate for mayor in 1913 five per cent. of the total vote. Let us take those districts in which he received over ten per cent. There are just ten such districts. Let us also put down the approximate percentage of the voters in these districts belonging to the principal nationalities. The following table gives these figures with the percentage of the vote given to the socialist candidate for mayor in 1913 and for governor in 1910:

Assembly District	Socialist Vote		Native of Natives	Austr.	Ger.	Irish	Italian	Russian
	1910	1913						
B 21....	12.4	16.1	12.6	5.9	4.1	0	9.1	31.2
B 23....	12.5	15.8	19.8	3.9	2.2	1.6	4.6	33.3
B 19....	11.0	12.8	12.6	.8	13.6	0	9.9	11.9
M 4....	12.6	11.9	7.0	25.2	.4	1.1	2.5	35.6
M 26....	10.2	11.8	7.1	6.7	4.6	3.8	1.4	34.6
M 8....	14.6	11.7	2.5	14.2	.7	0	4.1	54.4
M 22....	13.1	11.7	10.6	4.6	21.2	5.3	1.6	3.6
M 6....	10.0	11.2	2.4	30.8	1.1	.7	.7	30.4
M 24....	10.4	11.2	11.1	3.9	4.3	6.2	11.1	20.6
M 10....	11.1	10.8	5.9	12.5	4.7	0	13.9	22.3

It will be seen from the table, first, that the percentage of native born of native parents is less in every district than that of some foreign nationality; second, that in every district but two the percentage of Russians far exceeds that of any other nationality; third, that in those two exceptional districts it is the Germans that predominate. The Austrians should be added to the Russians, because, as said before, both Russians and Austrians in these districts are practically all Jews. Our conclusion therefore, is that the bulk of the socialist vote is derived from the foreign Jewish element, and to a much less degree from the Germans. This position is supported from the other end. The districts in which the socialists received the fewest votes, from 1 to 2 per cent., are those in which the natives, the Irish and the Italians are strongest—the first, third, fifth, seventh, ninth, thirteenth, fifteenth, twenty-fifth and twenty-seventh of Manhattan; and such districts as the second and third of Brooklyn.

The other branch of the question on radicalism resolves itself into this, "What voters are susceptible to influence from the Hearst newspapers?" One of the principal candidates in 1913 was bitterly opposed by these papers and a candidate of their own was nominated by the Independence League. Do the replies run to any extent along lines of national cleavage?

A study of the figures seems to justify the following observations: The districts in which the voters of native parentage are comparatively

few—less than one third of all the voters—are those in which the Hearstians are strongest. On the other hand, they are not strongest where the foreign-born voters are most numerous. Their hold is upon the native-born of foreign parentage. If we take the districts giving the Hearst candidates the largest percentage—say over eight per cent.—we find the foreign-born Germans and Irish far outnumbered by the natives of German and Irish parentage. If we take those giving the lowest percentages—say, less than four per cent.—we find the foreign-born of all nationalities greatly outnumbering the native. Along with these facts we find that several of those districts among the half dozen giving the highest socialist vote are also among the half dozen giving the lowest Hearstian vote, showing that socialism and Hearstism are but weakly correlated.

The half dozen districts highest for Hearstism, and half dozen lowest, with the percentage vote given both in 1913 and 1910 (when the league ran a candidate for governor) are given below.

HIGHEST FOR HEARST CANDIDATE

Assembly District	1913	1910
B 9	10.1	9.0
B 22	9.8	9.6
Bx 33	9.5	11.1
Bx 34	9.3	9.1
B 20	9.3	9.5
B 16	9.2	6.4

LOWEST FOR HEARST CANDIDATES

Assembly District	1913	1910
M 6	.5	3.6
M 4	1.2	3.0
M 8	1.6	3.2
M 3	2.9	3.4
M 2	3.0	3.4
M 27	3.2	2.9

Hearstism we conclude is a mode of thought that is attractive chiefly to members of the transition species between the immigrant and the American of native parents.

Finally, how do our naturalized citizens stand towards that latest phase of reform represented by the Progressive party? The answer to this question is made difficult by complicating circumstances. In 1912 the personal issue played an over-shadowing part; in 1913 interest was centered at other points, the aims of the Progressive party for the time being coinciding with those of other political elements. One or two facts in the election of 1912, however, are extremely suggestive even though they do not cover the whole ground. In that election Roosevelt ran ahead of Wilson in only four districts in the city. One was the twenty-third of Manhattan, in which Taft also

ran ahead of Wilson—a strong Republican district. The other three were the sixth, the eighth and the twenty-sixth, the three districts in which the Russians and Austrians constitute the great majority of the electorate.

It appears, therefore, from the experiment in social psychology conducted by the state in November, 1913, that, firstly, feudal politics as exemplified by Tammany is disapproved by native Americans (native born of native parents), by Russians and by Germans; it is favored by Irish and Italians; secondly, socialism is not a general foreign phenomenon, being preferred chiefly by Russians and, to a less extent, by Germans, getting no support from the Irish and but little from the Italians; thirdly, Hearstism is a transition phenomenon manifested by a considerable number of foreigners in process of becoming Americanized.

THE EVOLUTION OF SERVICE BY UNION AND COOPERATION, CONSERVATION AND EXCHANGE

By Professor WILLIAM PATTEN

DARTMOUTH COLLEGE

THE specialist, who has wandered far into the wilderness of created things, seeking the solution of his problem at its source, must pause now and again to note the location of the sun and the direction in which the streams are flowing. Having done so, he well may greet his distant colleagues and send a field-note of progress to his friends at home. Herewith is such a greeting and such a field-note of progress.

Part I

I. *Evolution and the Conduct of Life*

The theory of evolution is now accepted by all classes of intellectual leaders. Its transforming influence has penetrated society far beyond the point where the theory is formally recognized, or the meaning of the term even vaguely understood. It has destroyed old standards for the interpretation of life; erased old formulas for the conduct of life; and has compelled us to make new standards and formulas more in harmony with our new conceptions of nature and her methods.

With the disappearance of the old landmarks, the acknowledged leaders of humanity, of all kinds of belief and training, are groping about seeking a new standard for the interpretation and the conduct of life; a standard that is based on the best of the old religious, and on the best of the new knowledge; one that is not in downright conflict with the common-sense teachings of every-day life, nor with the conduct of affairs in which these leaders are the acknowledged experts; nor with the vision of the modern prophets who foresee the coming of a new man.

It is therefore again time to enquire what is the nature of the underlying processes common to the evolution of the living and of the non-living world? What, after all, constitutes progress in nature, and how it is accomplished? In what directions are the great evolutionary streams of plant life, and animal life, moving? What are the ethics and morals of nature, if indeed she has any? What has science to offer the trustees of tradition in place of that which it seems to have destroyed? What have the students of nature, and of life at large, learned, however elemental, that will be to all mankind a fundamental truth and a guiding principle to right living? Is mankind to live, and make

progress in his manner of living, by following the same laws other living things have followed in their progress; or must he create out of his own compelling needs new methods of living, new principles, new laws of conduct, that are solely applicable to himself?

To these questions science has given various answers, for life, as well as nature, has many sides, and science sees them through diverse eyes.

II. *The Mosaic Vision of Science*

Nature is, indeed, so vast, so intricate, that one science can see but a very small part of her; and since no science can long preserve its images undimmed, nor adequately utilize the vision of other sciences, our mental picture of nature is a mosaic patchwork of flickering images; a changing, composite caricature, that exaggerates her most conspicuous features, her most discussed and most recently discovered phases.

But yesterday, nature seemed to be the essentially unchanging product of a precipitative creative fiat; to-day, the still changing product of a slow process of growth; and to-morrow, what will the image be? Which science will throw the high lights of nature on the mind of man? Which one will cast the shadows?

The great naturalists of the preceding generation—those brilliant students of interwoven lives playing their varied parts on shifting scenes of forest, field, and shore—gave us our first vivid picture of an ever-changing nature. It was largely their testimony, and the overwhelming evidence gathered from their point of view, that won the verdict for evolution. After the great naturalists came the modern schools of biologists, exploring the streams of life to their source, and by greater refinements of methods seeking in the seclusion of the laboratory to obtain a nearer and a larger view of nature in accouchement: now scrutinizing with microscope and blazing lights the minutely woven fabric of egg, and sperm, and embryo; now seeking the first throbs of nascent life in cell and organ; now, by artful and instantaneous killing, striving to fix in their order the mincing steps of life, and to preserve them for more deliberate inspection; now striving to view the steps of life in action; and again, by mimicking the processes of life, hoping to catch their meaning, or perhaps the meaning of life itself.

The field naturalists and the modern schools of biologists survey a particular phase of life through a particular medium, or facet, and each school has evolved a set formula, or diagram, for the one thing it most clearly sees; notably the Lamarckians, who see the inheritance of acquired characters, and the moulding influence of habit and of the external environment; the Darwinians, who see little else than "natural selection" and the "survival of the fittest"; the Weismannians, who specialize in an omnipotent, but obedient, "germ plasma," and who insistently deny the inheritance of acquired characters; the morphol-

ogists, who see their own cubist diagrams, instead of living, growing things; the cytologists, breeders and experimentalists, with their thumbnail sketches of the minute machinery of life, and of heredity; with their now widely familiar Mendelism, chromosomes, tropisms, artificial parthenogenesis and eugenics.

The precise methods of the modern biologist may give us commendably accurate pictures of some particular point, or phase, of life, as life is at the present moment. They have, no doubt, greatly stimulated and enriched the science of biology; but they have not clarified it, nor unified it to a corresponding degree, because they have not given us large pictures of the processes and products of evolution; and because their formulas, when widely applied, are contradictory and often meaningless. They lack perspective, and for that reason they have not taken, nor can they take, the place of the descriptive and historic sciences, such as geology, paleontology and comparative anatomy. They alone can show us approximately what life was like in the remote past, the wonderful progress it has made, its method of making progress, and the order of its accomplishment.

Thus the multiplicity, and the changing intensity, of the images formed by the compound eye of modern science have created much confusion in the mind of the scientist and the layman; one that is augmented by a prevalent opinion that certain points of view, and certain methods of studying nature, are more "scientific," more truthful and more trustworthy than others.

It is clear that the microscopic, telescopic and panoramic methods of studying nature have their respective virtues and the defects of their qualities, for each method, and each point of view, shows important things the other fails to reveal. In their attempts to portray nature, biologists often forget the weakness of the one and fail to utilize the strength of the other. By thus limiting their field of vision; by exaggerating the minute, the local, the dramatic, and the tragic incidents of life, they overlook the most significant teachings of nature, although they are familiarly and universally proclaimed by her. The layman is always a loser thereby, for while the sicklied germs of truth fly far and wide on the white wings of explanatory lies, the mature plant is too deep rooted and ponderous to be successfully transplanted.

III. *Tragic, Cooperative, and Benevolent Nature*

The picture of nature painted by the field naturalists was a warring, hostile nature, "red in tooth and claw with ravine." Its merciless struggle for existence, its wanton destruction and tragic incident, as portrayed by their disciples, deeply moved both scientist and layman, and greatly influenced the conduct and the interpretation of human life.

But the attention of the naturalists was mainly focused on the fifth

act of life's drama, not on the body of the play; on the tumult and the decisive battles of a complex, mature life whose work was nearly done, not on its earlier, more primitive phases, nor on the silent, constructive processes, the building up of cell on cell, and organ on organ, that were taking place during the long and peaceful periods of preparation.

They gave us the now familiar picture of life's tragic side, and like all one-sided representations, it was but a caricature, true indeed to the life they portrayed, but misleading in the omission of the truth. They showed us the shameless selfishness; the needless toil and suffering; the wanton wastefulness of life; the endless competitions of strength and skill, in shifting alliance with cunning, hypocrisy and deceit; with blind chance in the background awarding death to the vanquished and to the victor life's bitter spoils.

With master strokes, and with the convincing accuracy of the trained observer, they painted the "disastrous chances" of a tumultuous life; the "moving accidents by flood and field"; the spectacular catastrophes of failure. But they did not portray the slow and benevolent processes of construction; the peaceful cooperations, the careful conservations, and the successful sacrifices of self to higher service. Some writers have indeed recognized the element of benevolence in the cooperation that forms such an important feature of social organization; but usually it has been regarded as something peculiar to the association of a few highly organized animals, and to man, not as something inherent to all stages of organic and inorganic nature.

But a new phase of the primeval method of nature, a new instinct, one that proclaims the universal brotherhood of man with man, and the brotherhood of man with all life and with nature, is seeking expression in the heart of man. It demands the so-called "humanitarian" methods of benevolent union, of cooperative exchange, of sympathy and service. The hand hesitates to obey the heart's commands, because the false prophets of science still dictate the use of nature's crudest, least effective methods, saying that progress can be made only through appropriation, elimination and destruction; through competition and then more competition; through mastery by brute force, or strategy; through selfishness; and the license of freedom uncontrolled. I challenge this interpretation of the order. It is not the real teaching of life, nor of nature. It places the emphasis in the wrong place and on the wrong thing. It measures the cost, but does not see the gain. It counts the failures, but does not recognize the manner of achieving success.

There is nothing new, essentially new, or unlike nature's methods, in the "humanity" of man, for the "humanitarian methods" of making progress through sympathetic, or harmonious, action; through benovelent union; through cooperative exchange and service, are as old

as the universe; and it is on these methods alone and with them alone, the universe is built. All evolution is a process of more and more successful union, and more and more effective cooperation. All manner of living is a fabric of cooperating services. In every sphere of nature, be it chemical, or physical, or organic, or social, or "spiritual," and at every stage in its progress, evolution is achieved through union, not disunion; through construction, not destruction; through sympathetic and harmonious action, not discord; through organization, not disorganization; through cooperation, not competition; through the bondage of service, not the license of freedom; through service that leads the way to more service, not through dominion and freedom from service.

The processes that produce evolution, as distinct from those that do not, are essentially benevolent and moral processes, for evolution is a progressive triumph of right, or successful methods of self giving. Every forward step is a constructing and a conserving process, whether it be the union of cosmic matter to form solar systems; or atoms to form chemical compounds; cells and organs to form a body; or man to form society. In all cases the forward step is the result of a successful giving, or surrender of self, to form a part of something that is larger, and better equipped for a wider service. Every living thing has its two great periods; one when it is receiving all it is, the other when it is giving all it has. The broader, more elaborate, each life is, the longer and more elaborate is the process of giving by the parents, and of receiving by the offspring; and the better all organs of both parent and offspring cooperate for a wider service of the whole.

Nor does "blind chance" rule in nature, for the dice are loaded in favor of things in the right time and place, as against those in the wrong time and place; in favor of things that cooperate and serve, as against those that do not cooperate and serve. In its broadest sense, union, even if it is primarily by "chance," tends to become progressive, or cumulative, because of the increased stability of each new product of union. Both union and cooperation are cumulative and directive; cumulative, because order tends to exclude from itself whatever is in conflict with it; directive, because the larger unit tends to control the smaller unit, and to incorporate it into its own system.

Progressive union and progressive cooperation, or progressive benevolence, harmony and service are, therefore, inherent properties of life and matter.

IV. *Creation, Evolution and Service*

Thus union and cooperation are the great creative, the great constructive, and the great conservative forces in nature. They tend to give community of action, and harmony of action to her constituents; to give stability and rest. They express themselves in an evolution that leads toward completion; toward the fulfilment of the inherent possibilities of nature; toward perfection.

Creation then is the birth of new things through the union and cooperation of preexisting things. Its product may be a new star; a chemical compound; an inanimate machine; a living mechanism with the properties of growth and renewal; or any one of the many kinds of cooperating groups, or associations, of men. We may not correctly use the term "Creative Evolution," for there can be no creation without evolution and no evolution without creation. The ceaseless flow of creative processes is evolution, and evolution is serial creation.

While nature's methods of creating are always the same, the quality of her products is as unknowable, and the extent of her resources as unpredictable, to-day as they were yesterday and as they will be to-morrow. The first cooperative union of hydrogen and oxygen to produce water created a new substance, with new properties and qualities, with new potentialities for world service, in no wise comparable with those of its constituents. This familiar process, whereby a substance, such as water, is produced by the cooperative union of things that appear to us so utterly unlike it, is no more or less mysterious in its power to create new things, new properties, new possibilities for further creation, than the cooperative union of a much larger number of elements to form protoplasm, with its newly created properties called "vitality."

As the formal chemistry of cooperating elements creates new chemical substances, with new properties and new powers for world service, so the super-chemistry of cooperating lives creates new organisms whose sum total of reactions may be expressed in unified bodily, or social activities, or in terms of bodily or of social consciousness, with their new powers for world service. These new properties, born of the cooperative union of a group of cells to form a "living body," or of a group of men to form a "team," a college, a city, or a state, constitutes the distinctive properties, or what is often called the "soul" or "spirit," of that group; and just as the properties of water and the "vitality" of protoplasm are new things, unlike anything else in the whole world, so are the essential, distinctive properties of each class of cooperating things unlike anything else in the whole world; hence they can only be measured, or compared, in terms of themselves.

The only attribute common to each class, and to all classes of nature's manifestations, is the inherent power, through the union and cooperation of their respective constituents, to create new things with new properties and with new powers for world service. The only common measure of their powers for service is the extent of the unions and cooperations that created them, and the extent of the new unions and cooperations they, in turn, create.

Progress therefore in organic evolution, as in cosmic evolution, consists in a measurable approach towards uniting the maximum number

of constituents into the most economic system of foreign and domestic cooperation.

Whatsoever conditions of time, space, materials and mode of action tend to give greater unity and better cooperation in nature, is world-service. Service, then, constitutes the real basis of ethics and of morality for the attainment of service is, to that extent, the actual fulfilment of the possibilities of nature; and all service is the fruit of a measurably perfected process of cooperative union.

Science, therefore, finds no time, nor place, nor thing set apart and alone sanctified by one instantaneous, all-embracing creative act. Cosmic evolution and organic evolution, the growth of suns and stars, of earth, and plant, and man, are continuous parts of one process. The formal chemistry of earth, and sea, and air; the flowing chemistry of protoplasmic cell and organ; the moulding discipline of associated nerve and muscle; of eye and hand; the alchemy of associated lives in nature's household, are but different phases of one living, all pervading, process of creation.

Nebulæ stiffen into stars, and suns give birth to drooling planets, larva smeared. Throbbing tides of sea and air, the heart-beats of a planet, drive the humid breath of oceans over the mountain skeleton, and through the capillaries of earth, clothing her ribs in clay, and spreading her first gardens of ooze. Earth labors in her kitchen, and with equal skill in synthesis, brings forth atoms tied in squads, or regiments; minerals, straight-edged and steadfast; soft proteids and albumens, with rounded forms and yielding sides; dancing specks and wriggling threads, prophets of the life to come; sprawling, self-constructing, self-consuming, protoplasm, free to rove, or wrapped in walls, or bound in glowing brotherhood of cells together; naked, hand-free, high-headed man, armored and armed with conscience and with vision. Scrutinize as best she may, science finds no seam in this universal fabric; no patchwork of dead and alive, honored or dishonored in creation; no boundaries between what was, and is, and shall be.

Thus all nature is a moving conflict for more intimate union, better cooperation, wider service. An unending strife to gain stability, or peace, where peace is won only through union and cooperation that lead to further conflict and wider service. All evolution is the product of service, and its progress is measured in terms of service. The essential character of all natural processes is a striving for perfection through organized service.

There should be no conflict between the teachings of science and the dictates of an enlightened humanity as expressed in the broad term religion, for science and religion are dual reflections of a universal natural law; their methods and aims are the same; they differ only in the manner in which they seek for, discover and express the same things.

Science seeks truth and discovers righteousness. Religion seeks righteousness and discovers truth. Both acquire knowledge of nature's right and wrong methods of making progress, and both point the same way to right living.

Science is the deliberate, conscious interpretation of nature. Religion is the instinctive, unconscious expression of natural law in terms of feeling.

Religion is the instinctive feeling for truth, justice and righteousness. Nature is truth, and her way is the way of justice and righteousness. Science takes cognizance of it in measured terms.

Religion is the feeling of wonder, adoration, gratitude and humility. It is largely justified and satisfied by the contemplation of nature through science.

Religion is the recognition of our own imperfections, and a desire for perfection. Nature is a conflict of imperfections. Science shows that the conflict is aimed at, and moves toward, perfection.

Religion demands service. Nature is a growing fabric of cooperating services. Science surveys the process and points the way toward higher service.

In science and religion, there is strife through organized service to discover and attain perfection. Each reflects in its own way the essential character of a universal natural law.

* * * * * * *

We are at present in a better position to use the panoramic vision of science than ever before, because we have now reached a point where the outlook on the evolution of life extends to the horizon, and we may see mapped out in broad perspective the grand preliminaries to life, and the general trend of life's highways.

These great highways of organic evolution, that run back for many millions of years, through the whole gamut of vertebrate and invertebrate life, from man to the simplest and minutest kinds of living things, show us in large terms what organic evolution really is and how it has been accomplished. They reveal to us the ethics and the morals of nature, the fundamentally right and the fundamentally wrong methods of living, for throughout all the highways of progress nature declares, and declares with insistent repetition, that the actual creation of new things and of new powers for service, or the evolution of the varied products and activities of nature, is never compassed by competition and selfishness; never by destruction, nor by discord, nor by dominion; but by union and by cooperation; by sympathy, submission and mutual service. Until some other being appears, greater than man, the age long processes that have produced him are justified by their product, and are thereby standardized as righteous and moral processes.

(To be continued)

THE PROGRESS OF SCIENCE

THE ADDRESS OF THE PRESIDENT OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE meeting of the British Association for the Advancement of Science in Canada, in South Africa and now in Australia exhibits those national traits which led to the founding and development of these dominions, and year after year the president of the association represents the leadership in science which the British races have so continuously maintained since the time of Roger Bacon. Recent advances in biological science are scarcely parallel in importance to the newer developments in physics, recounted before the association by Dr. Lodge last year, but the experimental and quantitative methods now being applied in genetics, as clearly explained by Professor Conklin in the present issue of this journal, are a beginning from which much may be expected. Professor William Bateson has been a leader, perhaps the chief leader, in this work, and his presidential address deserves attention both for the advances which he recounts and for the speculations in which he indulges.

The address—which in this country has been printed in full in *Science*—was divided into two parts, or it may rather be said that two addresses were made, one at Melbourne and one at Sydney. The first describes Mendelian genetics with special reference to its evolutionary aspects and its destructive side, the second is largely concerned with applications to man and to society. Professor Bateson tells us that in biological science we are just about where Boyle was in the nineteenth century; we can dispose of alchemy, but we can not make more than a quasi-chemistry. Still, he is pretty positive, not only in his destructive criticism, but also about the wide implications of his quasi-chemistry.

If, as Professor Bateson tells us, genetic research can only obtain new varieties by crossing, and if new traits can only be exhibited by the loss of inhibiting factors, we are certainly put to ignorance in regard to the entire process of evolution. This is doubtless where we have always been, for no biologist now supposes that natural selection can account for the origin of variations. Darwin did not, but assumed variability to be a natural function of organisms. Mendelism is supplying a vast amount of new and exact knowledge in regard to the results of crossing and hybridization, but in so far as it can not explain the origin of those variations which have led to new species and organic evolution, it only exhibits our failure in this direction. Professor Bateson says: "We have to reverse our habitual modes of thought. At first it may seem rank absurdity that the primordial forms of protoplasm could have contained complexity enough to produce the diverse types of life." But this is what the mechanical theory of life presupposes, and how we are helped by assuming, as Professor Bateson does, that the differentiation that gives rise to new species is due entirely to the loss of factors rather than to the addition of factors, it is difficult to see. The proposition that we all have the genius of Shakespeare and Newton, but that they were able to exhibit it owing to the loss of inhibiting elements appears to be purely mythological.

Professor Bateson and other Mendelians are doubtless correct in regarding the doctrine of natural selection and the survival of the fittest as a kind of philosophical truism, but it is not clear

why this is more true of separate traits than of the organism as a whole, or how the theory is affected by modern work in experimental genetics. Indeed, the occurrence of mutations makes it easier to understand the results of natural selection, for the larger variations may have a definite value to the species when the smaller variations which might have lead up to them would not.

In his second address Professor Bateson says that at every turn the student of political science is confronted with problems that demand biological knowledge for their solution, but it does not appear that most of Professor Bateson's own generalizations—whether correct or not—are based on genetic research. For example, he urges that it can not be granted without qualification that the decline in the birth-rate of the intelligent and successful part of the population is to be regretted. He says that if the upper strata of the community produce more children than will recruit their numbers, some must fall into the lower strata and increase the pressure there. But it is by no means certain that there is too great pressure of population in France, Germany, England and the United States, and it would seem that an increase of intelligence and energy in the so-called lower classes would be a gain.

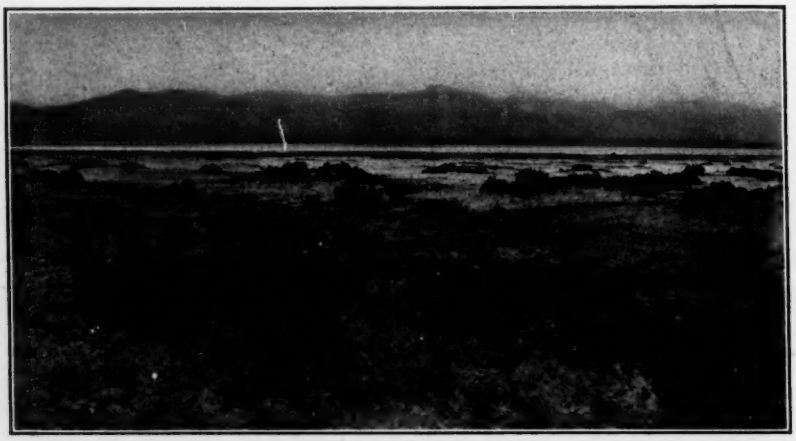
In so far as the small birth-rate of the upper classes is not so disastrous as some authors urge, it is because these classes owe their position to privilege rather than to ability, and if the privileged classes do not produce enough children to fill the positions of influence, men of greater ability may be found.

Professor Bateson says: "Modern statesmanship aims rightly at helping those who have got sown as wildlings to come into their proper class; but let not any one suppose such a policy democratic in its ultimate effects, for no course of action can be more effective in strengthening the upper classes whilst weakening the lower." Here and elsewhere Professor Bateson seems to misunderstand the proper meaning of democracy, which is not that all individuals are equal, but that each should have opportunity according to his ability.

A COMPREHENSIVE STUDY OF A DESERT BASIN

THE making of the modern Salton lake in the sink of the Cahuilla basin in 1905 and 1906 was due directly to the opening of canals for irrigation from the Colorado River leading into the bowl and a coincidence of flood water from the main tributaries of the river. The director of the Desert Laboratory of the Carnegie Institution, Dr. D. T. MacDougal, formulated a plan for systematic measurement of the various physical and biological changes accompanying the recession of this lake and the results of the activities of the members of the staff of the Desert Laboratory and other collaborators are given in Publication 193 of the Institution.

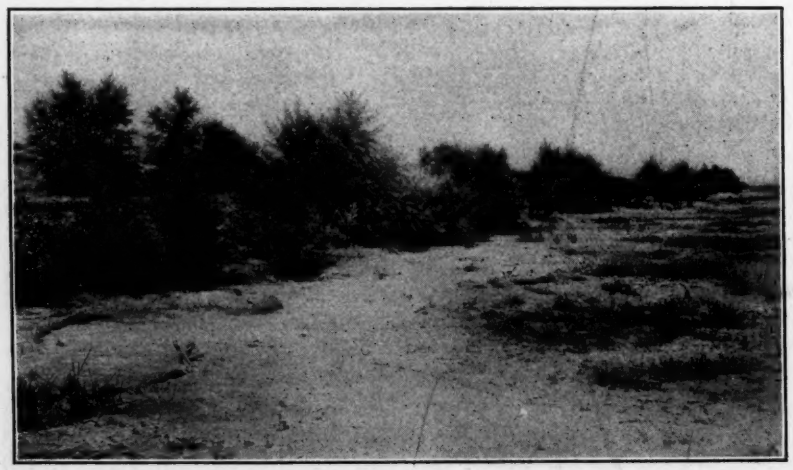
Scarcely had the level of the lake begun to fall and the salts to become more concentrated, when it was noted (in 1911 that calcium was being lost from a solution not near the saturation point for carbonate, and in 1911 a distinct coating of lime was recognized on the branches of submerged trees. Such deposition seemed to be associated with the activities of certain bacteria and algæ, and to constitute the first stage in the formation of the travertine left by previous lakes. Investigation of this matter is still in progress, as well as that of the disappearance of potassium from the lake water which is now plainly apparent. The principal changes in plant tissues submerged in the Salton were studied by President M. A. Brannon, of the University of Idaho, who found bacteria of the Amylobacter group were present, which produced a hydrolyzing action on the unlignified parts of vegetable tissues. Coincidently, Professor G. J. Peirce, of Stanford University, followed the behavior of some of the organisms which endure the entire range of variation from fresh to brackish water and finally to brine in



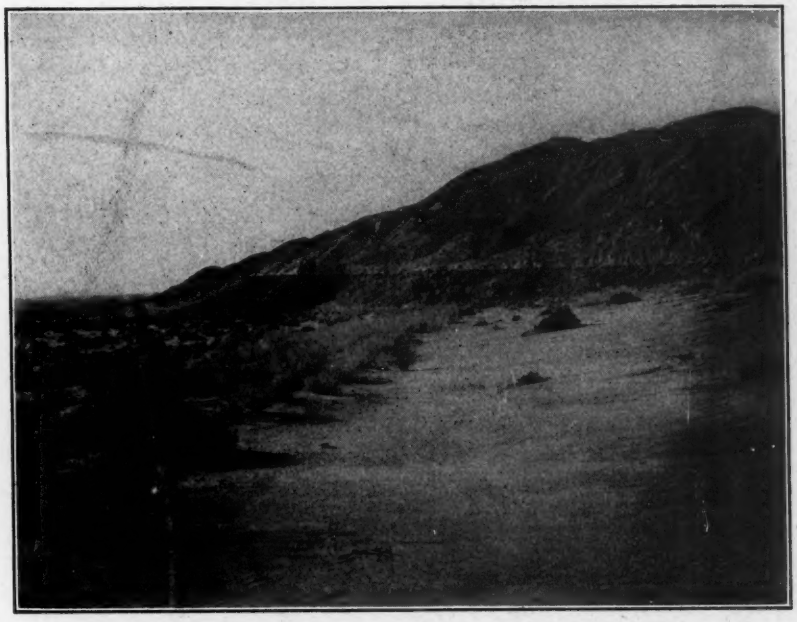
SALTORN AT BOTTOM OF SALTON SINK IN THE CAHUILLA BASIN, February, 1903.

the pools around San Francisco Bay, with a view to anticipating events in the slower concentration of the Salton, which has now reached a stage of slightly more than one per cent. brine.

It is eloquent of the arid conditions of the Cahuilla that the sink, or the region formerly occupied by Blake Sea, with an area of over two thousand square miles, bears only 8 species of trees, 33 shrubs and woody plants, and 81 herbs, or a total of 122 species, about the number that might be expected in a square mile in the Mississippi Valley, or on the eastern sea-board. Small as this number may be, the stage seems to be set for the appearance of new ones, as evidenced by the number of endemic forms. *Striplex Saltonensis, Sphæralcea orcuttii, Cryptanthe costata, Astragalus limatus, A. aridus* and *Chœmæsyce Saltonensis* occur so far as known in this sink, which must have been occupied by Blake Sea within four or five centuries. That they have ever lived elsewhere or before this can not be demonstrated, and their occurrence suggests most strongly a recent localized origination. The modifications in *Aster exilis, Prosopis glandulosa, Striplex canescens,* and *Scirpua paludosus* shown by individuals on emerged



RANK OF VEGETATION AT UPPER MARGIN OF TERRACE FORMED BY RECESSION OF SALTON LAKE DURING 1911.



DESERT FORMATION ON STRAND THREE OR FOUR HUNDRED YEARS OLD NEAR TRAVERTINE POINT. Ancient high level shore-line of Blake Sea on cliffs.

strands and abandoned shores of the present lake are additional facts of interest in this connection.

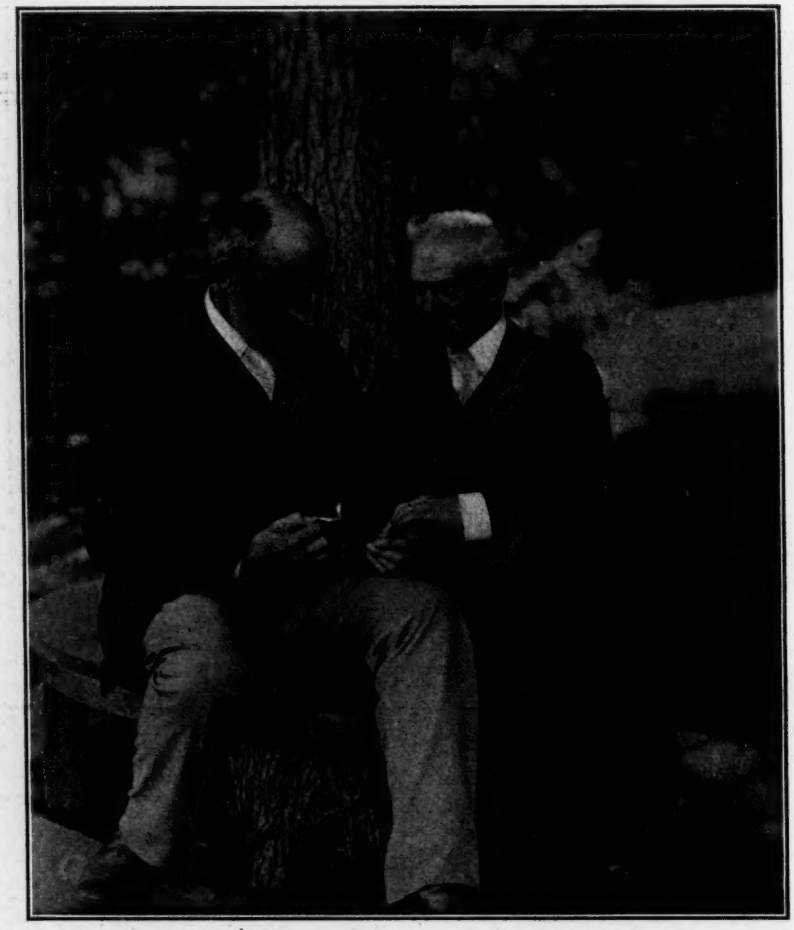
Not since the sterilization of the island of Krakatoa by a volcanic explosion has an opportunity been offered for the study of the biological reoccupation of such an area, and in this case the entire course of change has been kept under careful observation. Sixty species of plants appeared in dense strand formations on the beaches during the first seven years. Successions were rapid toward the desert, and within three years after the emergence some strands bore two species which were characteristic of the beach ranks four centuries old.

Even greater interest attaches to the revegetation of hills emerging as islands and which had been seed-sterilized. To these were borne seeds by winds and waves, but not with certainty by birds. Conjoined observation and experiment showed that the seeds for many plants which float or sink germinate, and the buoyant seedlings float for weeks, when stranded by chance their active roots strike into the mud within a few hours, making this an effective type of dissemination which appears to have escaped attention hitherto.

SCIENTIFIC ITEMS

WE record with regret the death of James Ellis Gow, professor of botany in Coe College; of Mr. Alfred John Jukes-Brown, F.R.S., lately of the English Geological Survey; of Dr. Edouard Reyer, professor of geology at Vienna, and of Lieutenant Sedoff, while leading an Arctic expedition to Franz Josef Land.

THE American Chemical Society is unable to hold the meeting which had been planned for Montreal in September. Nearly all international scientific congresses and conferences, including the International Congress of Americanists, which was to have met in Washington in October, have been postponed. The New Zealand meeting of the British Association has been abandoned. A number of distinguished American men of science went to attend the meeting as guests of the New Zealand govern-



This photograph, taken on the summit of Mount Washington twenty years ago, shows Professor Hugo Kronecker, the distinguished physiologist of the University of Berne, whose recent death is deplored by many students throughout the world, feeling the pulse, at that time intermittent, of Professor Henry Pickering Bowditch, of Harvard University, long the leader of physiology in the United States.

ment.—It is announced that the British universities will open as usual in the autumn, though about half the students have enlisted in the army. The Rhodes scholars from the United States and from the British colonies are expected to be in attendance at Oxford.—It is said that all German universities will be closed.

In future the distribution of the Nobel prizes will take place on June 1 instead of in December, as hitherto. The next distribution has been fixed for June 1, 1915.